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# Feed Manufacturing Effects On Poultry Feed Quality And Nutrition

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The most important cost factor when producing poultry is feed costs. Feed represents up to 65% of the cost of growing broilers. How that feed is prepared, mixed, and manufactured impacts the nutritional quality and costs of production. When many nutritionists today are asked “what is the importance of feed manufacturing to the nutrition of poultry?” most will recall the importance of pellet quality, and others will recall how certain nutrients could be damaged during processing. However, few of us tend to think of the feedmill as a kind of ‘chemistry lab’ in which heat, time, and reactants are combined to form a final product. Many years ago when we thought about the feedmill, it was just a place to mix cereal grains into a mash feed, but today, with new enzyme technology, developing antibody additives, genetically modified grains, and new processing techniques, the feedmill will become more integral to the feed formulation process. Yesterday, we worried about getting adequate nutrients to the bird, tomorrow we will worry about the entire process. Those who are able to utilize the correct time, temperature, and chemical reactants that result in the most economical feed at economical processing charges will produce lower cost products.

When thinking about today’s feed manufacturing process, it may require thinking out of the box just a bit. For example, is water in a formula all that important other than knowing that too much is a bad thing, that it has no caloric content and that you have to pay for transportation costs to the farm? What about the conventional dogma that says that to improve pellet quality you simply need to increase the gelatinization of the cereal starches, which we have all been led to believe will improve poultry nutrition? Is this true?

Almost all animal feed nutritionists are taught the importance of water as a nutrient at least in the sense that it present in high amounts in animal tissues. Since water makes up 60-70% of all animal tissues and products, it is required by the animal in large quantities. Not many nutritionists consider water when formulating feed. This could be because of concerns with feed quality when stored since elevated levels could result in mold growth.

However, adding water to feed will decrease the cost of making pellets and could improve feed conversion and growth rates. When given a choice, birds will choose feed with added water because it is more palatable to them. They tend to consume more wet feed than dry, even after the level of moisture is adjusted. It has been shown in bird growth competitions, that birds fed feed with water grow at a faster growth rate.

Feed manufactures work hard to produce pelleted diets of high quality while minimizing production expenses (Mommer and Ballantyne, 1991). Pellet quality (intact pellets) greatly improves broiler growth and feed conversion (Briggs et al., 1999). Fairchild and Greer (1999) have demonstrated that increasing feed mash moisture at the mixer can increase pellet durability and decrease pellet mill energy consumption, consequently improving pellet quality and reducing milling expense. Decreasing pellet mill energy consumption alone provides an incentive for feed manufacturers to consider moisture addition during the manufacturing process. However, potential improvement in pellet durability adds even more enticement for the use of moisture in broiler feeds since past research has illustrated positive relationships between pellet quality and broiler feed efficiency (Moran, 1989; Nir et al., 1994). The evidence these past studies provide warrant further research involving the application of pelleting broiler feeds with added water as well as determining the effect of this process on broiler performance.

We have found that moisture addition to feed mash generated extensive differences in pellet durability and starch gelatinization between low moisture and high moisture treatments. High moisture pellets for both starter and grower diet formulations produced higher durabilities and gelatinization percentages compared to their respective low moisture equivalents. Broiler performance was most markedly affected in the three-to six-week period. Pelleted treatments produce significantly higher live weight gains and feed efficiencies compared to mash treatments. Surfactant/water additions to high moisture treatments created a dilution of nutrients. Adjusted feed efficiency values illustrated that high moisture pelleted treatments produced significantly higher feed efficiencies compared to any other treatment. A possible explanation for these findings is that broilers fed high moisture pellets were able to better utilize feed energy for growth (productive energy) as opposed to using feed energy for food prehension (maintenance). Broilers fed intact pellets of high durability would expend less energy in the act of feeding compared to broilers fed pellets of low durability and high percentages of fines. This speculation has been supported in past research (Moran, 1989; Nir et al., 1994). Mortality was not affected by moisture additions; however, pelleted treatments produced significantly greater mortality percentages compared to mash treatments.

We have begun to conduct other studies with the primary objective of clarifying the relationships between moisture addition, pellet manufacturing and quality, nutrient density and broiler performance. Differences in formulation density significantly affect pellet quality. The production rate of the formation of pellets where treatments have adjusted formulation densities produced higher rates of production as compared to non-adjusted formulations. This finding may be the result of the high soybean oil content of the adjusted formulations, which would aid in lubricating the pellet die. Adjusted formulation treatments produced pellets of significantly lower durabilities and higher percentages of fines as compared to NRC formulated treatments. Nonetheless, when the experimental treatments' pellet qualities were compared to that of the control treatments, moisture addition significantly improved durability and decreased the percentage of fines. This finding is especially important since the adjusted formulation treatments contained high percentages of soybean oil. Past research has shown that increasing fat above 2% in a corn-soybean broiler diet prior to pelleting will decrease pellet quality with respect to durability and the percentage of fines (Richardson and Day, 1976). In some of our studies, fat added at 6.5% prior to pelleting in conjunction with added moisture can produce pellets of 75% durability and less than 27% fines. These results conclude that the addition of moisture, even if ordinary tap water, can potentially increase pellet mill production rates and significantly increase pellet quality. Broiler performance was similarly unaffected by moisture type additions, however formulation density can significantly impact performance, if left unadjusted, of course. Broilers fed adjusted formulation treatments exhibited significantly higher live weight gains and significantly lower feed intakes that collectively produced significantly higher feed efficiencies.

These data support the adjusted feed efficiency calculations derived in the first study. Mortality percentages were not affected due to experimental treatments. The adjusted formulation diets were the only treatments to improve live weight gain compared to their control treatment. The two control treatments were superior in regards to feed efficiency compared to their corresponding experimental treatments. This finding was probably a result of both controls being more nutrient dense than their respective experimental treatments, which caused feed intake to be significantly decreased. Contrary to the speculations of the first study, the adjusted formulation control, which possessed the lowest durability of all treatments produced the highest feed efficiency value. It should be noted, however that the live weight gains produced by the adjusted formulation control were the lowest of all treatments, despite this formulation having the most concentrated nutrient profile (growing broilers in this manner would not be cost effective). A possible explanation for this finding could be that the current study was conducted through the months of March and April during ideal broiler-rearing outside temperatures, whereas broilers in the previous study were reared during the much colder months of November and December. Ideal outside environmental temperatures could have dictated a lessened need for broiler maintenance energy. Nir et. al. (1994) define productive energy as net feed energy less bird maintenance energy. Although improved pellet quality would be expected to increase productive energy, this energy gain could be in excess relative to low maintenance energy requirements as well as the fixed protein content of the diet. Past research has also illustrated that broilers raised from 3 weeks to marketing during favorable outside environmental temperatures demonstrated decreased feed efficiency despite improved pellet quality (Acar et al., 1991). Mortality percentages did not differ among control treatments and experimental treatments. These data conclude that adjusted broiler grower diet formulations that include added moisture of either experimental type prior to conditioning and pelleting may improve (3-6) week performance, without negatively acting on broiler survivability.

Problems concerning feed mold should be insignificant since feed moisture content in both studies did not exceed 16%. Poultry can be negatively affected by feed mycotoxins produced by the fungi

*Fusarium, Aspergillus* and *Penicillium*. However, these fungi require a minimum moisture content of 19 to 25 percent (Trigo-Stockli and Herrman, MF-2061), though few nutritionists would be comfortable with this level.

Feed manufacturing produces physical and chemical changes in ingredients, and these may include the gelatinization of starch. The effect of gelatinized starch on animal performance has been inconsistent in past research. Broiler diets typically contain high percentages of grain and, therefore, high proportions of starch. Under processing conditions using heat and moisture, starches gelatinize and help bind feed particles together (Mommer and Ballantyne, 1991). Hoover (1995) defines starch gelatinization as an order-disorder phase transition that includes the diffusion of water into a granule, hydration and swelling, uptake of heat, loss of crystallinity and amylose leaching. Leached amylose immediately forms double helices that may aggregate (hydrogen bond) to each other and create semicrystalline regions (Thomas et al., 1998). Lund (1984) speculates that as the gelatinized starch cools, the dispersed matrix forms a gel or paste-like mass that may function as an adhesive or binding agent. Past research has associated dietary gelatinized starch both positively and negatively with pellet quality and broiler performance (Moritz et al., 2001; Moritz et al., 2002a; Moritz et al., 2002b). However, it has been speculated that gelatinized starch per se may affect broiler performance aside from its contribution to pellet binding.

Gelatinizing cereal starch has generally been thought to improve enzymatic access to glucosidic linkages and consequent digestibility (Moran, 1989; Colonna et al., 1992). Allred et al. (1957) reported a significant improvement in weight gain and feed conversion in chicks fed pelleted/re-ground corn that was incorporated into a complete diet over chicks fed similar diets with unprocessed corn. However, later research examining processed/re-ground corn-based diets concluded there was no nutritional benefit to broilers despite increased diet starch gelatinization (Sloan et al., 1971; Naber and Touchburn, 1969). Moreover, (Plavnik et al., 1997) found that feeding broilers pelleted/re-ground corn-based diets resulted in decreased bird performance compared to broilers fed similar unprocessed diets.

One strategy for producing high quality pellets has been to gelatinize as much ingredient starch as possible. High quality pellets are desirable as they are correlated with improved broiler performance. However, improving pellet quality through increasing starch gelatinization may negatively affect nutrient utilization, thus antagonizing performance enhancements of pelleting.

In the current study, corn was processed using typical feed industry practices and incrementally incorporated into complete diets at the expense of unprocessed corn (UC). The objective was to create diets with different levels of gelatinized starch produced from different commercial processes. Corn was the only ingredient manufactured to avoid confounding processing effects of high fat or high protein ingredients. Corn was either pelleted (PC) or extruded (EC) and subsequently re-ground prior to diet incorporation. Pelleted corn provided dietary starch gelatinization percentages indicative of conventional pelleted feeds, while EC provided extreme levels of gelatinization. Diets were fed to broilers during the 0-to-3-week starter phase to determine effects of processing-derived starch gelatinization on performance.

Unprocessed and processed corn types had numerically similar bulk density post-grinding. Creating this similarity was important since dietary starch density may influence broiler feed intake (Naber and Touchburn, 1969). Moisture content of diets relative to nutrient density may also influence feed intake (Moritz et al., 2001; Moritz et al., 2002a). However, moisture percentages among corn types were similar, and corn was not the only ingredient contributing to dietary moisture. Despite grinding unprocessed and processed corn through the same hammer mill screen, particle size among corn types differed. However, standard deviations among corn type particle size were similar. Starch gelatinization percentages were calculated relative to unprocessed corn (1). Pelleting and extruding corn increased starch gelatinization 29 and 92%, respectively. The diet containing 3/3 pelleted corn had a similar percentage of calculated gelatinized starch as the diet containing 1/3 extruded corn. Peak gelatinization temperatures were similar among corn types.

Interactions between processed corn type and level of inclusion were not apparent. Feeding broilers diets that utilized pelleted corn resulted in lower feed intake and higher feed efficiency compared to broilers fed diets containing extruded corn. Broiler live weight gain and mortality were not affected by processed corn type. The performance differences may be explained by variations among corn type particle size. Corn particle size of mash diets has been shown to influence feed preference, weight gain, growth efficiency and metabolism of broilers (Portella et al., 1988; Healy, 1992; Nir et al., 1994; Nir et al., 1994). The particle size of pelleted corn in our study averaged 231 μ m less than extruded corn. Healy (1992) found that decreasing the particle size of dietary cereals (corn, hard sorghum or soft sorghum) from 900 to 300 μ m in 200 μ m increments resulted in a linear increase in 0-to-3-week broiler FE (P = 0.001). For corn-based diets, improved FE was associated with decreased broiler feed intake and increased metabolizable energy corrected for nitrogen, but (Healy, 1992) did not statistically analyze broiler performance produced by individual cereals. Wondra et al., (1995) found that reducing the particle size of dietary corn from 1,000 to 400 μm in 200 μm increments in mash and pelleted diets linearly increased finishing pig FE (P < 0.001). The increase in pig FE coincided with a linear decrease in average daily feed intake (P < 0.002) and increase in digestibility of gross energy (P < 0.001). The authors suggest that reduced particle size increases surface area and makes nutrients more accessible to digestive enzymes.

Nir et. al., (1994b) observed significant 1-to-3-week FE and LWG improvements for broilers fed diets containing 900 μ m corn compared to broilers fed diets containing either 1,000 or 2,000 μ m corn. The authors speculate that these differences may have occurred due to changes in the gastrointestinal tract. In a subsequent study, Nir et al., (1994c) found that broilers fed coarse grain (2,000 μ m corn, wheat or sorghum) had higher gizzard weight at 21 d of age compared to broilers fed similar grain of 600 or 1,000 μm (P = 0.01). Similarly, (Healy, 1992) observed significant increases in 23 d broiler gizzard and proventriculus weight when broilers were fed 900 μm cereals as compared to 300 μ m cereals. Nir et al., (1994c) propose that physiological changes in the gastrointestinal tract may effect broiler appetite and feed passage rate. Healy (1992) speculates that gastrointestinal tract organ weight may affect maintenance energy requirements of broilers.

Inclusion level of gelatinized starch in general did not affect broiler performance parameters. However, increasing dietary inclusions of pelleted corn resulted in a linear decrease in broiler feed intake and weight gain. The aforementioned studies concerning particle size reported similar dietary effects on feed intake (Healy, 1992; Nir et al., 1994b; Nir et al., 1994c; Wondra et al., 1995). Since LWG paralleled feed intake and FE was not affected (P = 0.3009), it does not appear that increasing gelatinized starch through pelleting or decreasing particle size improved nutrient digestibility. Increasing dietary inclusions of extruded corn, which increased gelatinized starch and particle size, did not significantly affect broiler performance, although broilers fed diets that contained increasing amounts of extruded corn showed a numerical trend of decreased FE.

Live weight gain of broilers fed the control diet were lower than LWG produced by diets containing either pelleted or extruded corn. However, LWG did not significantly differ between broilers fed the control diet and the diet containing 3/3 pelleted corn. Additionally, feed intake and FE were similar among diets containing pelleted corn and the control diet. These findings are inconsistent with past research on dietary particle size (Healy, 1992; Nir et al., 1994b; Nir et al., 1994c; Wondra et al., 1995). Perhaps particle size differences were too small between diets containing pelleted and unprocessed corn to significantly affect broiler performance. Most previous studies used 200 μ m increments, whereas the difference in our study was less than 110 μ m. In contrast, feed intake increased (P = 0.0158) and FE decreased (P = 0.0179) when broilers were fed diets containing extruded corn as compared to the control diet.

Diets that incorporated pelleted corn, containing low levels of gelatinized starch, seemed to effect broiler feed intake as opposed to nutrient utilization. Sibbald (1977) found that steam pelleting various diets, which included a corn-soybean chick starter diet, did not change dietary true metabolizable energy. Bayley et al., (1968) fed broilers various corn-soybean mash diets from 0-23 d. The authors found no significant difference in energy metabolism or performance between broilers fed diets containing pelleted/re-ground corn and unprocessed corn. Diets that incorporated extruded corn, containing comparably high levels of gelatinized starch, seemed to affect broiler feed intake through decreasing nutrient availability, since broilers eat to meet there requirements. Sloan et al. (1971) fed diets containing unprocessed and expansion-extrusion processed corn to broilers from 0 to 4 weeks. The diets were described as similar in texture and bulk. The authors reported no significant difference in weight gain or feed utilization among broilers fed diets containing unprocessed corn and diets containing varying levels of processed corn. However, (Hongtrakul et al., 1998) found that feeding diets containing extruded cereals (corn, cornstarch, broken rice, wheat flour, and grain sorghum) to pigs from 0-7 d post-weaning decreased gain to feed ratios compared to pigs fed diets containing unprocessed cereals ($P < 0.05$).

The authors also varied extrusion processing conditions of corn to create diets containing increasing levels of gelatinized starch. Feeding pigs these diets from 0-18 d post weaning had a quadratic effect on dry matter, crude protein and energy apparent digestibility ($P < 0.01$). Digestibility values initially increased then decreased with increasing levels of gelatinized starch. The authors attributed these effects to variations in extrusion processing conditions, which may have generated retrograded starch, Maillard products and loss of available amino acids and/or vitamins.

Gelatinization percentage for diets containing 3/3 pelleted corn and 1/3 extruded corn were calculated to be similar. However, feed intake was significantly increased for broilers fed diets containing 1/3 extruded corn compared to broilers fed diets containing 3/3 pelleted corn. Despite differences in particle size, broilers fed each diet had LWG that imitated feed intake and had statistically similar FE. This finding does not follow typical particle size relationships found in the literature (Healy, 1992; Nir et al., 1994b; Nir et al., 1994c; Wondra et al., 1995), and perhaps is more indicative of extrusion processing impairing nutrient availability and requiring broilers to consume more feed to meet nutritional requirements.

In general, variation in diet particle size confounded effects of gelatinized starch on broiler performance. However, particle size was likely influenced by starch gelatinization. When performance effects could not be explained by particle size, the amount and derivation of gelatinized starch in diets may have influenced feed intake and/or nutrient utilization. Broiler feed intake may have been modified due to the effect of gelatinized starch on appetite, feed passage rate, gut morphology and related factors. Extrusion processing may have reduced nutrient availability of corn. Nevertheless, the data suggest that gelatinizing starch through commercial feedmilling processes does not improve nutrient utilization of broilers during the 0-to-3-week starter phase.

Particle size may well be the next real area of research in poultry nutrition. All forms of poultry have been fed ground diets for many years since it has been thought that the gizzard was able to adequately reduce all feed particles to the preferred size. As a result, the gizzard atrophies since it has less function. However, the gizzard may well have other not completely understood functions. Some workers have shown that the gizzard retains larger Soybean meal particles longer and does not release them to the small intestine until the mean diameter is actually smaller than had they ground the particles to a small size before feeding (Kilburn and Edwards, 2004). The birds were able to obtain more phosphorus from the ration when fed diets with large SBM particles. Thus, poultry may be able to function more fully if the gizzard remains in good condition. If the gizzard is able to retain more function when given less ground particles, the same might be considered for the remainder of the digestive tract. Does course ground grain improve the tone and integrity of the digestive system of poultry? This is an important question to consider since better muscle tone could lead to less breakage of the intestinal tract and thus fewer concerns with microbial contamination in the processing plant. More work is desperately needed in the area of particle sizes for poultry.

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## Notes

1. Starch gelatinization was determined by differential scanning calorimetry (DSC) (DSC7, Perkin-Elmer, Norwalk, CT) and calculated on a dry matter basis. Enthalpy values were determined by a computer integrator for peaks in the approximate temperature range for corn starch. The percent of starch gelatinization was determined by subtracting the enthalpy of the unprocessed sample from the enthalpy of the processed sample and dividing the difference by the enthalpy of the unprocessed sample. The method used for this analysis included: holding the sample for 1 min at 30°C, then heating from 30°C to 130°C at increasing temperatures of 10° per min.

# Field Evaluation Of A Fullfat Soybean Meal Obtained With The Use Of An Expander In Poultry Rations

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## Summary

The use of an optimum quality fullfat soybean meal (FFSBM) in terms of protein solubility and availability is critical at any layer or broiler operation that looks for a maximum operation efficiency and profitability. For this reason, the protein digestibility index of a fullfat soybean meal obtained with the use of an expander (EFFSBM) with 37.3% of crude protein, 91.15% of protein solubility in potassium hydroxide, 0.06 of urease activity and 3.6 mg/gr of trypsin inhibitor was compared to a soybean meal (SBM) with 48 % of CP and a protein solubility index of 85.45%, 0.19 of urease activity and 2.5 mg/gr of trypsin inhibitor, in commercial rations for Ross broilers and both soybean products were obtained from the same source of soybeans. Soybean meal was used in T-1 and the EFFSBM in T-2 being both isocaloric and isonitrogenous. The difference in terms of CP, TSAA, lysine, threonine and tryptophane content between T-1 and T-2 in relation to T-3, then between T-3 and T-4 and finally between T-4 and T-5 was based on the percentage of difference in terms of protein solubility between the EFFSBM and the SBM, this time of 5.7% and equivalent to 0.42% of protein, considering that 7.4% of the total protein was supplied by the EFFSBM after including it at 20 %. The EFFSBM was then incorporated into starting and finishing broiler rations with different levels of protein (22% for T-1 and T-2, 21.58%, 21.16% and 20.74% for T-3, T-4 and T-5 respectively in the starting period, and 18% for T-1 and T-2, 17.58%, 17.16% and 16.74% for T-3, T-4 and T-5, respectively for the finishing period). At 49 days no statistical difference ($p>0.05$) was observed among treatments for body weight gain (2617, 2621, 2636, 2631 and 2587) and feed conversion (1.988, 1.938, 1.946, 1.986 and 1.992).

The results obtained with this test allow for the presumption that when the expander is used to process soybeans into FFSBM, it is possible to obtain an additional benefit of 5.7% more in terms of CP, TSAA, lysine, threonine and tryptophane, due to a greater digestibility value resulting from the processing method. Knowing more about this new type of processing will allow the poultry industry to count on a more digestible source of both protein and energy, to meet the every time greater demand for highly digestible, good quality protein sources, of the new layer or broiler genetic lines. In addition to this, to count on this new type of EFFSBM will allow the poultry industry to optimize the use of protein in the rations, to reduce the metabolic load of excessive amounts of nutrients, and to formulate rations closer to the actual nutritional needs of the birds, all this always in favor of a better performance. Finally, for a better environment, the less nitrogen in the ration, the less potential pollution.

## Introduction

For many years soybean meal (SBM) was considered a by-product derived from the oil industry (Kohlmeier, 1993). However, the massive consumption of SBM by the poultry and the swine sectors, forced the oil crushers to look for better ways to improve oil extraction, seeking to preserve the nutritional value of the SBM.

Ever since the poultry and swine industry started a process of modernization in the 60's, where it was evident the industry needed of several ingredients to compound their feed. However, during the 80's, these type of rations were simplified towards including less ingredients, and ending up in the use of mainly corn and SBM (Fernandez et al., 1994). At this respect in a study conducted by Kohlmeier (1993), it became evident that in the United States a higher demand for soybean meal came along with a smaller demand for other secondary protein sources, mainly those from animal origin. This situation was more critical when the first cases of Bovine Spongiform Encephalopathie (BSE or so called Mad Cow Disease) were registered in the EU, reaching the point when these ingredients were totally banned for their use in feed in some countries, and shifting to a more reliable protein source like SBM.

Through the years the soybean processors worldwide have been able to produce different kinds of SBM, most of the times extracting the oil with the use of solvents, although sometimes it was mechanical extraction. In relatively recent years, the feed industry adopted a new practice, the inclusion of fullfat soybean meal, which in most cases was obtained through extrusion, either wet or dry, and some other times using roasters if the final users were the ruminants. The typical composition of a full fat soybean meal (FFSBM) shows an ingredient with 7 to 12% moisture, 33 to 40% CP, 16 to 20% fat and between 5 and 6% fiber (Kohlmeier, 1993).

Regardless of the variation in the nutritional value of the different soy products based on quality, the soybean itself and the processing conditions and method, SBM continues to be the protein source for excellence, as FFSBM is for energy.

Although the use of FFSBM in poultry rations is already a well accepted practice in most parts of the world, it is advisable to continue doing research around this ingredient, seeking to increase its versatility and to do it more adaptable to the actual nutritional, environmental and economical needs of the poultry and feed industry. No doubt that every time worldwide the livestock sector is facing more restrictions to operate, from sanitary, when the animal protein sources are being banned, to ecological when the impact of manure deposition is limited.

Maybe one processing technology that is still not well known and that is the objective of this study, is the use of expansion. The concept of this type of equipment is conceived as a simplified, low cost extruder. The expander is able to generate heat above 90°C through a hydro-thermal process, that results in the expansion of the ingredients (Broz, 1997). Right from its beginning in Europe, in most of the pelleting processes, the expander is located between the conditioner and the pelleting machine, a practice that has been used for over 15 years. Only the introduction of expanders with high capacity output has enabled a common feed plant to apply HTST (High Temperature Short Term) technology on the factory floor with satisfactory results in terms of product quality as well as in terms of economic efficiency. The very rapid spreading of this technology worldwide can be considered revolutionary and proves expanders as reliable and competitive machines. (Peisker, 1994).

For the feed industry, the advantages of using an expander go from the simple processing of ingredients to the production of finished feeds. The temperature reached in this equipment not only allows to destroy pathogens, but also to inactivate anti-nutritional factors, like trypsin inhibitors in soybeans. At the same time this type of process allows to maintain a high protein solubility index, making of EFFSBM a more digestible ingredient.

Nowadays the industry and the society demand the production of more digestible feed, as a means to reduce the negative impact of disposing an excessive amount of nitrogen and phosphorus to the environment. A situation like this takes place when protein is fed in excess, or when the protein source has a poor digestibility index. At the end, the less nitrogen in feces, the less in the soil, and so the smallest the risk to pollute the environment (Weigel, 1999).

This way, recent research studies have been destined to generate information that allows the nutritionists to formulate rations according to the ideal protein concept. This concept not only considers the fact that the minimum nutritional requirements for maximum performance are covered, but also that the metabolic load is reduced when nutrients are included in excess.

Recently, the American Soybean Association in Mexico knew about the capability of a Mexican company, Avicultores y Productores El Calvario S.A. de C.V. (AYPECSA), to process soybeans with the use of expanders for what ASA collected samples for their study. After analyzing the samples, it was evident that the FFSBM obtained with an expander had a higher protein solubility index (of 92% in average), while it kept a low urease activity (0.06) and low levels of trypsin inhibitors, these last one no higher than 4 mg/gr. These results, besides knowing which are the needs of the poultry industry, encouraged ASA to conduct a feeding trial destined to evaluate the nutritional value of this new FFSBM. There is good scientific evidence that the protein solubility test conducted on representative samples of SBM or FFSBM shipments is correlated to performance in the field.

No scientific journal reports a similar trial or evaluation, for this reason the present test is a unique work, which will serve as reference for future work on this matter. This time the test was conducted in broilers, being the largest market for soy products in the world.

## Materials And Methods

The trial was conducted at the Instituto Internacional de Investigacion Animal, S.A. de C.V., located at Villa del Marquez Queretaro in Mexico, at 1,800 meters above sea level. A total of 1,400 one-day old Ross broilers, with an average weight of 46.2 gr. were used at this test. Upon arrival at the farm, the birds were randomly assigned to four treatments (T-2, T-3, T-4 and T-5) and one control group (T-1) with seven replicates of 40 birds each (20 males and 20 females).

The birds were housed in an experimental farm, similar to a regular poultry house, over a 10 cm thick chopped barley hay bed, providing only water during the first two hours after arrival and after that feed was provided.

**Table 1. Composition and nutritional content of the starter diets (0 to 21 days of age)**

| | T-1 SBM 22% CP | T-2 EFFSBM 22% CP | T-3 EFFSBM 21.58% CP | T-4 EFFSBM 21.16% CP | T-5 EFFSBM 20.74% CP |
|---|---|---|---|---|---|
| Corn | 561.50 | 539.62 | 549.00 | 560.00 | 566.20 |
| Soybean meal | 366.00 | 170.00 | 172.00 | 170.00 | 163.00 |
| Corn gluten (60%) | 0.00 | 18.50 | 10.68 | 6.00 | 0.00 |
| Soybean Oil | 29.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| Calcium phosphate | 17.70 | 17.45 | 17.60 | 17.60 | 17.60 |
| Calcium carbonate | 14.17 | 14.00 | 14.00 | 14.00 | 14.00 |
| Salt | 4.15 | 4.08 | 4.07 | 4.07 | 4.07 |
| Sodium bicarbonate | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Choline chloride | 0.45 | 0.00 | 0.50 | 0.12 | 0.10 |
| DL-Methionine | 2.60 | 2.35 | 2.40 | 2.45 | 2.50 |
| Mineral premix | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Vitamin premix | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| HCl-Lysine | 0.90 | 1.20 | 0.90 | 0.70 | 0.55 |
| Monensin | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Flavomycine | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| EFFSBM | 0.00 | 200.00 | 200.00 | 200.00 | 200.00 |
| L-Threonine | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 |
| Canola meal | 0.00 | 29.80 | 26.20 | 22.10 | 29.00 |
| ME Kcal/Kg | 3002 | 3009 | 3008 | 3016 | 3012 |
| CP (%) | 22.00 | 22.00 | 21.58 | 21.16 | 20.74 |
| TSAA (%) | 0.968 | 0.972 | 0.957 | 0.945 | 0.938 |
| LYSINE (%) | 1.300 | 1.302 | 1.272 | 1.240 | 1.217 |
| THREEONINE | 0.847 | 0.848 | 0.840 | 0.814 | 0.801 |
| ARGININE (%) | 1.469 | 1.402 | 1.391 | 1.371 | 1.353 |
| TRIPTOPHANE (%) | 0.239 | 0.243 | 0.241 | 0.237 | 0.234 |

*Ca 1%, available P, 0.48%, Na 0.22%, choline 1500 mg/Kg*

**Table 2. Composition and nutritional content of finishing diets (22 to 49 days of age)**

| | T-1 SBM 18% CP | T-2 EFFSBM 18% CP | T-3 EFFSBM 17.58% CP | T-4 EFFSBM 17.16% CP | T-5 EFFSBM 16.74% CP |
|---|---|---|---|---|---|
| Corn | 632.10 | 613.85 | 626.70 | 640.00 | 652.81 |
| Soybean meal | 271.00 | 118.50 | 107.70 | 96.70 | 85.80 |
| Corn gluten (60%) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Soybean oil | 49.80 | 21.50 | 19.30 | 17.00 | 14.80 |
| Calcium phosphate | 14.48 | 14.48 | 14.30 | 14.30 | 14.45 |
| Calcium carbonate | 12.50 | 12.23 | 12.43 | 12.43 | 12.50 |
| Salt | 4.15 | 4.10 | 4.10 | 4.10 | 4.10 |
| Sodium bicarbonate | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Choline chloride | 0.84 | 0.60 | 0.65 | 0.68 | 0.72 |
| DL-Methionine | 2.80 | 2.82 | 2.82 | 2.82 | 2.79 |
| Mineral premix | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Vitamin premix | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| HCl-Lysine | 0.42 | 0.00 | 0.05 | 0.05 | 0.09 |
| Monensin | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Yellow pigment | 8.45 | 8.45 | 8.45 | 8.45 | 8.45 |
| Flavomycine | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| EFFSBM | 0.00 | 200.00 | 200.00 | 200.00 | 200.00 |
| L-Threonine | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| ME Kcal/Kg | 3199 | 3201 | 3200 | 3200 | 3199 |
| CP (%) | 18.00 | 18.00 | 17.58 | 17.16 | 16.74 |
| TSAA (%) | 0.861 | 0.879 | 0.868 | 0.858 | 0.844 |
| LYSINE (%) | 0.999 | 0.999 | 0.974 | 0.945 | 0.919 |
| THREONINE (%) | 0.738 | 0.735 | 0.719 | 0.702 | 0.688 |
| ARGININE (%) | 1.170 | 1.156 | 1.126 | 1.093 | 1.080 |
| TRIPTOPHANE (%) | 0.190 | 0.199 | 0.194 | 0.189 | 0.183 |

*Ca 0.85%, available P, 0.40%, Na 0.22%, choline 1500 mg/kg.*

The EFFSBM utilized at this feeding trial was obtained with the use of a Desmet expander, with a processing capacity of 10 MT/hour. Having 37.3% CP, 91.15% protein solubility in KOH, 0.06 of urease activity and 3.6 mg/gr. of trypsin inhibitor, the EFFSBM that was incorporated to practical starter (0 to 21 days) and finishing (22 to 49 days) broiler rations, with different levels of protein. The starter diets had 22% CP in both T-1 and T-2, and of 21.58%, 21.16% and 20.74% for T-3, T-4 and T-5, respectively. For the finishing period, the level of CP was of 18% for T-1 and T-2, and of 17.58%, 17.16% and 16.74% for T-3, T-4 and T-5, respectively. The SBM used in the study was obtained from the same source of soybeans that were used to obtain the EFFSBM, and had 48% CP, 85.45% of protein solubility index, 0.19 of urease activity and 2.5 mg/gr of trypsin inhibitor. The difference in terms of CP, TSAA, lysine, threonine and tryptophane content between T-1 and T-2 in relation to T-3, then between T-3 and T-4 and finally between T-4 and T-5 was based on the percentage of difference in terms of protein solubility between the EFFSBM and the SBM, this time of 5.7% and equivalent to 0.42% of the crude protein, considering that 7.4% of the total protein was supplied by the EFFSBM after including it at 20%.

### *Parameters Evaluated*

During the test, the following parameters were evaluated, weight gain, feed consumption, feed conversion corrected to mortality, and percentage of mortality at 21, 35 and 49 days of age.

## Results

### *Starting Phase (0 To 21 Days Of Age)*

In relation to feed consumption, at the end of this period a significant statistical difference ($p<0.05$) was registered among treatments, being the highest in T-1 and the lowest in T-2, T-3 and T-5 (Table 3). In terms of weight gain, T-1 containing SBM was significantly higher than the rest of the groups. The variance analysis for feed conversion did not show any significant difference ($p>0.05$).

In general terms, the values obtained with the four groups that contained EFFSBM had a similar response, with a slight trend towards a higher weight and feed conversion when there was a higher concentration of nutrients.

**Table 3. Results for the starting phase (0 to 21 days of age)**

| Treatment | Feed Consumption (G) | Weight Gain (G) | Feed Conversion (Feed/wt gain) |
|---|---|---|---|
| T-1 | 1113 a | 674 a | 1.651 a |
| T-2 | 1050 b | 651 b | 1.612 a |
| T-3 | 1054 b | 640 b | 1.645 a |
| T-4 | 1081 ab | 644 b | 1.677 a |
| T-5 | 1064 b | 640 b | 1.662 a |
| Probability | P<0.003 | P<0.0001 | P<0.10 |

*Means within columns with no common superscript differ significantly (p<0.05)*

### *Growing Phase (22 To 35 Days Of Age)*

During this period no significant difference ($p>0.05$) was observed among treatments for feed consumption, weight gain and feed conversion (Table 4).

**Table 4. Results for the growing phase (22 to 35 days of age)**

| Treatment | Feed Consumption (G) | Weight Gain (G) | Feed Conversion (Feed/wt gain) |
|---|---|---|---|
| T-1 | 1725 a | 917 a | 1.880 a |
| T-2 | 1705 a | 930 a | 1.834 a |
| T-3 | 1697 a | 930 a | 1.825 a |
| T-4 | 1711 a | 913 a | 1.874 a |
| T-5 | 1691 a | 903 a | 1.872 a |
| Probability | P<0.22 | P<0.09 | P<0.10 |

*No significant differences between treatments (p>0.05)*

There is a numerical trend towards a better weight gain when EFFSBM was included in the rations with an equal or slightly less nutrient density than the control group (T-1) containing SBM, and also a slight decrement in body weight when nutrient density was reduced in the diets with EFFSBM. The best feed conversion ratios were obtained in the four treatments where EFFSBM was included, mainly when the nutrient density was higher.

### *Finishing Phase (36 To 49 Days Of Age)*

For feed consumption, there is statistical difference ($p<0.05$) between treatments, where T-1 and T-4 obtained the higher values, but with no significant difference among them, but so with treatments T-2 and T-5. When weight gain was analyzed and so feed conversion, no significant difference ($p>0.05$) was observed among treatments (Table 5). Again numerically a better weight gain and feed conversion were observed in the birds that consumed the rations containing EFFSBM and with a higher nutrient density.

**Table 5. Results for the finishing period (36 to 49 days of age)**

| Treatment | Feed Consumption (G) | Weight Gain (G) | Feed Conversion (Feed/wt gain) |
|---|---|---|---|
| T-1 | 2381 a | 997 a | 2.389 a |
| T-2 | 2324 b | 1029 a | 2.258 a |
| T-3 | 2355 ab | 1022 a | 2.304 a |
| T-4 | 2395 a | 995 a | 2.406 a |
| T-5 | 2315 b | 1031 a | 2.244 a |
| Probability | P<0.03 | P<0.72 | P<0.23 |

*Means within columns with no common superscript differ significantly (p<0.05)*

### *Analysis With All The Phases (0 To 49 Days Of Age)*

When all the parameters were analyzed using the data accumulated to the end of the trial, a significant difference was found ($p<0.05$) for feed consumption, being higher for T-1 and T-4.

**Table 6. Performance with all the phases (0 to 49 days of age)**

| Treatment | Feed Consumption (G) | Weight Gain (G) | Feed Conversion (Feed/wt gain) |
|---|---|---|---|
| T-1 | 5203 a | 2617 a | 1.988 a |
| T-2 | 5081 b | 2621 a | 1.938 a |
| T-3 | 5130 ab | 2636 a | 1.946 a |
| T-4 | 5228 a | 2631 a | 1.986 a |
| T-5 | 5154 b | 2587 a | 1.992 a |
| Probability | P<0.008 | P<0.50 | P<0.07 |

*Means within columns with no common superscript differ significantly (p<0.05)*

However, no significant difference among treatments was observed for weight gain and feed conversion (Table 6).

The three groups containing the EFFSBM and with a higher nutrient density numerically obtained a better weight and feed conversion than the control group (T-1) containing SBM.

## Conclusion

1. The adequately processed EFFSBM is an ingredient with a higher availability of protein and aminoacids, probably due to a higher protein solubility index and in absence of anti-nutritional factors, mainly trypsin inhibitors, which in this case were not higher to 4 mg/gr, according to what the literature recommends (Dale, 1989).

2. The inclusion of EFFSBM in 20%, with a protein solubility index of 91.15% allowed to reduce the concentration of CP, TSAA, lysine, threonine and tryptophane by 5.7% in relation to a SBM with 85.45% of protein solubility, without affecting weight gain, or feed conversion in broilers to 49 days of age.

3. The protein solubility in EFFSBM is at least 91.15%, which is 6.15% higher than the average of the best of SBM in the market (with 85%). This validates that the EFFSBM is a better processing method in terms of preserving protein quality, while inactivating the anti-nutritional factors.

4. Given that T-3, T-4, T-5 had less protein and aminoacids, but had a similar performance among them, it can be deduced that there is a positive effect on performance when higher quality ingredients are used, probably due to a lower metabolic load. This last issue might suggest that it can be possible to reduce the safety margins of nutrients in the formula.

5. The test clearly shows that both SBM and EFFSBM, when adequately processed, are ideal for broiler feed, and that the combination of both ingredients (in this case up to 37%) contributes to obtain excellent economical and production results.

6. It is well documented that the laboratory level of KOH is a reliable predictor of in vivo performance.

7. In relation to the processing of EFFSBM, it is important to determine which are the ideal operating conditions for each piece of equipment (temperature, moisture and time), so that the plant obtains the desired EFFSBM quality.

8. Due to the fact that the cost of processing with expanders is similar to the cost of extrusion, this new processing method can be consider viable for the existing poultry integrators.

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# Broiler Breeder Nutrition And Management (Part I)

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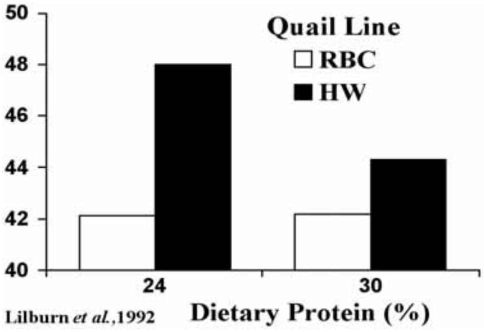
## Genetics, Nutrition And Reproduction

Poultry breeding remains largely based on classical quantitative genetics. In essence, pedigree broiler candidates are full-fed nutritionally-dense and properly balanced diets to allow individuals that have the greatest potential to utilize crude protein (CP) and metabolizable energy (ME) to grow fast, convert feed efficiently, and yield well to become apparent by their performance. Thus, broiler strains are often selected on high-protein, high-energy diets. Selection on nutrient dense diets apparently necessitates nutrient-dense diets in order for the progeny to fully express their genetic potential. An excellent example of the relationship between genetic progress and appropriate nutritional compensations can be taken from research with quail (Lilburn et al., 1992). Random-bred Japanese quail were placed on a selection program intended to create heavy weight (HW) quail. These quail were full-fed 28% CP diets for 28 days and then the largest birds were selected and mated to produce the next generation. When these birds were reared to sexual maturity on a 24% CP diet, as recommended by the National Research Council (NRC, 1984), there was an obvious delay in sexual maturity (onset of egg production).

When the HW quail and the non-selected random-bred control (RBC) quail were fed a range of diets differing in % CP from hatch to sexual maturity a nutritional-genetic interaction became evident. The RBC quail, when fed the NRC recommended 24% CP diet from hatch, matured sexually at about 42 days of age. In contrast, the HW quail exhibited delayed sexual maturity on the same diet. However, when the HW quail were fed a 30% CP diet, more like that fed during their pedigree selection process, the delay in sexual maturity was noticeably reduced (Figure 1). These data make the strong suggestion that declining reproductive function due to genetic selection for non-reproductive traits may in some way be ameliorated nutritionally.

**Figure 1. The effect of dietary crude protein (% CP) during rearing on age at onset of egg production of quail selected for heavy 28-day body weight (HW) and a random-bred control (RBC) population (Adapted from Lilburn et al., 1992).**



## Interaction Of Nutrition, Temperature And Lighting Program

The very important interaction between climate, photostimulation, and nutrition can be illustrated by examining the seasonality of broiler breeder reproduction in temperate climates. The differences in so-called “in-season” and “out-of-season” breeders have historically been attributed to daylength. However, the interaction between daylength and seasonal differences in temperature and feed intake provide an alternative explanation of seasonality. In-season breeders are generally the better performing birds in a temperate climate. These birds typically hatch in warm periods of the year when daylengths are long. Daylength and temperature both decline during the rearing period. As broiler breeders have typically been fed to achieve a body weight standard, the cool weather at the end of the rearing period dictates more feed be fed. Thus, the cumulative nutrition is adequate for in-season breeders if photostimulation is not too early. In contrast, out-of-season birds hatch in the cool season and are reared while both daylength and temperatures are increasing. As the birds approach the age of photostimulation in warmer temperatures, they require less feed to achieve the standard body weight and thus have less cumulative nutrition at the point of photostimulation. This causes a delay in onset of egg production and is frequently the case for tropical countries. Many managers respond to this with earlier photostimulation, but this often does not correct the problem. Increasing the target body weight has often been used as a "treatment" for out-of-season (hot temperature grown) birds because, as we now know, having a heavier body weight effectively increases the cumulative nutrition in the warmer weather (see discussion below).

Another method of correcting delayed onset of egg production in warm weather has been to delay photostimulation until sufficient cumulative nutrition has been achieved. With this latter approach, body weight will not become excessive, but this approach may not work as well as increasing the cumulative nutrient intake to 20 weeks of age. If the current genetic trend toward improved feed efficiency continues, breeders will have to be photostimulated much later and/or grown to a higher body weight at 20 weeks of age in order to accumulate sufficient nutrition for proper responsiveness to photostimulation.

At this point, it should be stated that photostimulation plays a major role in the overall process of nutrient accumulation. Photostimulation somehow changes the birds from a "nutrient-accumulating" to a "nutrient-expending" organism. This is the probable reason that age at photostimulation has been delayed with good results in modern feed-efficient lines of broiler breeders. An extended rearing period is needed for some birds to accumulate sufficient nutrition for optimum reproduction. As shown below, this is certainly true for females (Walsh, 1996; Walsh and Brake, 1997; 1999) and one can interpret the large body of French literature to mean the same for males (de Reviers, 1977; de Reviers, 1980; de Reviers and Williams, 1984; de Reviers and Seigneurin, 1990). In these male data, most heavy-line male fertility problems could be avoided by simply not photostimulating the birds and thus giving them unlimited time to accumulate sufficient nutrients necessary to sustain optimum reproduction before actually achieving sexual maturity. The act of photostimulation can obviously interrupt the process of nutrient accumulation.

## The Concept Of Minimum Cumulative Nutrition

During recent years, our laboratory has examined the relationship between cumulative nutrition during the rearing period and subsequent female reproductive performance. The rearing period was defined as the time from placement at one day of age to photostimulation at 20 weeks of age. Four groups of broiler breeders of the same strain are compared in Table 1 (Peak and Brake, 1994). Photostimulation was at 141 days of age. Table 1 shows the cumulative CP, ME, body weight at 140 days, and subsequent eggs per hen housed. The groups were fed the same diet during rearing, but the feed was allocated differently each week to achieve the cumulative differences. There were apparently no great differences in female body weight, but when the birds were photostimulated at less than ~22,000 kcal cumulative ME and ~1200 g CP, there was a reduction in eggs per hen of ~15. This suggests that there was a ***minimum*** nutrient intake, irrespective of body weight, required to obtain acceptable levels of egg production.

**Table 1. Cumulative nutrient intake prior to photostimulation1 and egg production**

| Breeder Group2 | Cumulative @ 20 wk ME | CP | Body weight3 @ 20 wk | Eggs per hen housed (25-64 wk) |
|---|---|---|---|---|
| | (kcal/bird) | (g/bird) | (kg) | (n) |
| BB1 | 25397 | 1397 | 2.06 | 159.8 |
| BB2 | 22207 | 1221 | 1.86 | 164.6 |
| BB3 | 20792 | 1144 | 1.98 | 149.4 |
| BB4 | 18985 | 1044 | 1.87 | 149.7 |

*1 Photostimulation was at 141 days of age. (Adapted from Peak and Brake, 1994)*
*2 Each group was comprised of 2400 birds.*
*3 All birds weighed at 140 days of age.*

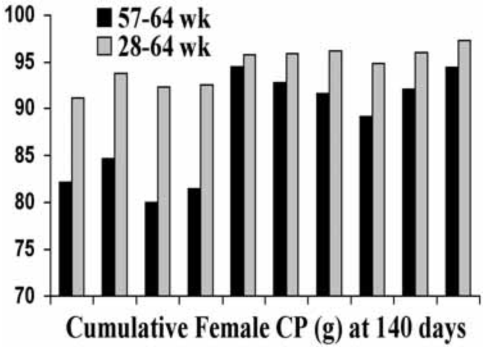
A recent review of NCSU broiler breeder research flock data revealed that in 1988, females were grown to a 140-day body weight of ~2.0 kg with ~28,000 kcal cumulative ME. Comparative data from 1998 shows that this 2.0 kg body weight could be achieved with as little as 20,000 kcal cumulative ME. This difference is probably due to the remarkable genetic progress made in broiler feed conversion. This may explain why photostimulation has been required to be adjusted from 126 days in 1983 to 154 days or later today. With improved feed conversion, it may simply take longer to accumulate the necessary nutrition for a proper response to photostimulation.

## Fertility In The Female

The fact that cumulative CP nutrition at photostimulation can have a significant effect on female fertility has been clearly defined (Walsh, 1996; Walsh and Brake, 1997, 1999). The female contributes to fertility through mating receptivity and spermatozoal storage in special sperm host glands in the oviduct. This was demonstrated by VanKrey and Siegel (1974) where broiler line genetic selection proceeded on nutrient-dense broiler diets while typical lower protein and energy rearing diets were used for parent stock. Evidently, inadequate CP (amino acid) nutrition prior to photostimulation, irrespective of female body weight, leads to poor persistency of fertility.

Data summarized in Figure 2 show cumulative fertility for several female experimental groups from 28 to 64 weeks of age along with the fertility for the last 8 weeks of production (57 to 64 weeks of age). The latter is a good indicator of persistency of female fertility as all males were managed in a similar manner across all experimental groups. It is also important to note that the effects of nutrition and management during rearing and the early breeding period are often seen only very late in the breeding period. From Figure 2, it is clear that there is a minimum cumulative CP intake of ~1200 grams CP or greater at photostimulation (141 days) for females, irrespective of body weight. This projected minimum assumed that the total lysine, on a corn-soy-based diet, was 5% of crude protein and methionine + cystine were 83% of lysine.

**Figure 2. Graphic summation of data that demonstrates the effect of cumulative intake of CP prior to photostimulation on overall fertility as well as fertility during the last 8 weeks of the production cycle (Adapted from Walsh, 1996).**



## Feeding Programs For Yield-type Broiler Breeders

It has been noticed in the USA that females reared with males often produce more eggs than females reared sex-separate. In order to understand this observation, a study (Mixgrow) was conducted to determine the effect of mixing males with females at different ages. Yield males were full-fed on an 18% CP diet until mixed with females at two, four, six, or eight weeks of age. The yield females received an 18% CP diet for one week followed by a 15% CP diet to photostimulation. The feeding programs for the various male treatments are shown in Figure 3 along with the female feeding program. The female feeding program used was one that had been shown to be successful for the "standard" type of broiler breeder pullet. Female body weights were virtually identical across male treatments. The male body weights reflected a dose response to increased amounts of feed prior to mixing. Cumulative fertility is shown in Table 2. These fertility numbers are lower than optimum because males and females were fed together after 21 weeks of age to exaggerate the effect of cumulative nutrition during rearing and to allow the males to be exposed to a decreasing feed allocation after 35 weeks of age. In spite of this, some of the pens with the eight-week mixed males exhibited fertility in excess of 90% at 64 weeks of age without any body weight control or separate feeding. The later mixing age males (six and eight weeks) were more resistant to the feed reduction after peak egg production because they reached sexual maturity with a greater nutrient reserve. A conservative estimate of cumulative nutrient consumption by the males to 21 weeks of age (photostimulation) based upon planned male and female intake is shown in Table 2. The actual feed intake of the males mixed with females at six weeks

**Figure 3. Feed consumption of males reared separate to 2, 4, 6 or 8 weeks of age and that of the females that they were mixed with at the indicated ages (Adapted from Peak et al., 1998).**

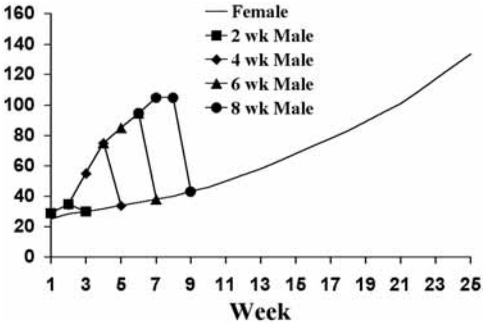
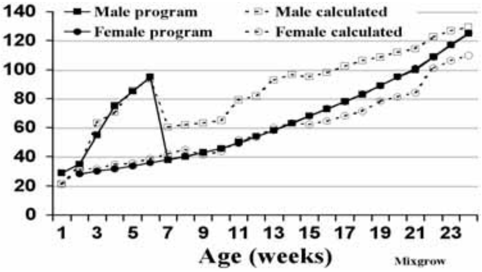


**Table 2. The estimated minimum cumulative nutrient intakes of males started separate and mixed with females at 2, 4, 6 or 8 weeks of age**

| Male | Cumulative @ 21 wk | | Male body weight | | | Cumulative |
|---|---|---|---|---|---|---|
| mixing (wk) | ME (kcal/bird) | CP (CP/bird) | @ 21 wk (kg) | @ 31 wk (kg) | @ 60 wk (kg) | fertility (%) |
| 2 | 23750 | 1245 | 2.77 | 4.64 | 5.68 | 66.9 |
| 4 | 25125 | 1345 | 3.11 | 4.75 | 5.72 | 68.5 |
| 6 | 27350 | 1500 | 3.21 | 4.77 | 5.95 | 76.6 |
| 8 | 30225 | 1690 | 3.66 | 4.95 | 5.95 | 85.2 |

of age (as an example) and that of the females can be estimated from the body weights taken from all birds every two weeks using the formulas of Combs (1968). The results are projected in Figure 4.

**Figure 4. Calculated and programmed feeding of males and females mixed at 6 weeks of age shown in Figure 3. Programmed feeding was the actual amount of feed fed (shown in Figure 3) and the calculated feed consumed was based upon calculations from actual body weights of males and females based upon the formulas of Combs (1968).**



The males consumed about 125% to 150% of the female feed intake depending upon age when mixed and body weight. This would give an actual cumulative ME intake of over 34,000 kcal and 1600 grams of CP for both the six week and eight week mixed males. This agrees with other data from our laboratory with separate-grown males. The data also show that the real pattern of female feed consumption (Figure 4) differed significantly from the programmed pattern, especially after 14 weeks of age. This must be extremely important as females that were grown sex-separate on the programmed female feed amounts laid ~35 fewer eggs per hen. These data (and field experience) suggest that larger feed increases late in rearing (in blackout where there is little reproductive development) for "yield-type" pullets results in excessive body weight and excessive "fleshing" (breast meat development). Much has been said about the need for good "fleshing" in "standard" strains of parent stock but the situation is much different for the "yield-type" pullet. Excess breast meat appears to reduce egg production.

We must be careful to not give too much feed too early (before onset of lay) as we may simply increase female body weight, primarily breast meat, and cause reproductive problems such as peritonitis. The excess breast meat probably increases maintenance and inhibits reproductive development. This may be why heavy breasts relative to fat pad develop when feed increases are too rapid in "yield-type" females. These birds with excess breast meat relative to fat pad tend to exhibit a reduced appetite in hot weather (even in tunnel-ventilated and evaporatively cooled houses), increased susceptibility to heat stress, poor peak egg production and lay poorly thereafter. A conservative feeding approach both before and after photostimulation would be advisable with "yield" females until one becomes familiar with the particular strain of broiler breeder in the specific situation. It is better for the hens to be late coming into production than to exhibit high mortality and poor egg production. These problems are uncommon with a "standard" type broiler breeder hen.

In a manner similar to the need to modulate any large increases in feed intake, diets should be formulated to minimize abrupt changes in composition that will create situations that are similar to abrupt changes in the feeding rate. A single dietary ME for all diets is recommended to assist production managers maintain consistent feed increases. Similarly, modern broiler breeders may respond robustly to abrupt changes in protein with an unexpected increase in body weight. A smooth transition among starter-grower-breeder diets or starter-grower-prebreeder-breeder diets should be considered during feed formulation. It is suggested that total lysine levels be ~5% of crude protein and methionine + cystine be ~0.60-0.63% of the diet for most feeds. It is probable that "yield-type" females perform better with a slightly lower protein ***breeder*** feed than can be fed successfully to a "standard" female. A 16% CP diet with ~0.80-0.82% total lysine should be sufficient to support egg production without producing excessive amounts of breast meat.

## Dietary Protein And Metabolizable Energy For Broiler Breeder Males

Few data exist that link intake of ME during rearing to breeding performance. However, the findings of Vaughters et al. (1987) indicated that a relationship between ME consumed during rearing and fertility may exist. Our data (Table 2 above) suggest a minimum cumulative ME intake of ~30,000 kcal prior to photostimulation. However, most data suggest that reproductive fecundity is directly related to daily ME intake during the breeding period and that daily ME intake should somehow be proportional to body weight and body weight gain. It should be stated that Parker and Arscott (1964) and Sexton et al., (1989b) observed that decreased fertility was preceded by decreased dietary ME intake during the breeding period. In cages, Attia et al. (1995) fed Ross males 300, 340, or 380 kcal ME per day. They found no fertility differences, but did note increasing testis weights with increasing ME intake. In floor pens from 26 to 60 weeks of age, Attia et al., (1993) found the 300 kcal ME males to weigh less and have lower fertility than the males consuming 340 and 380 kcal ME per day. These data clearly show a differential effect of ME intake in cages versus floor pens due to the difference in relative activity levels. All the birds in cages probably received enough ME to satisfy their reproduction requirements. However, in the floor pens, it appeared that the birds on the lowest ME intake did not receive enough nutrients for reproduction due to the increased maintenance requirement required for increased activity.

It is also very interesting that these authors found a dose-related decrease in 42-day broiler weights with decreasing ME allocation to the breeder males. Presumably, these data suggest that males that have the potential to produce the largest broilers require more ME to breed in natural mating conditions. These data also suggests that excessive efforts to control male body weight can reduce broiler performance.

Confusion about optimum diets for males began when Wilson et al. (1987a) fed 12%, 14%, 16%, and 18% CP diets to males from four to 53 weeks of age. The 10 males used per treatment were placed in cages at 14 weeks of age. There was no lighting program detailed in the manuscript and is presumed to be natural daylight during rearing with artificial supplementation at some unspecified point. Cumulative CP to 21 weeks was 1220 grams and 1385 grams, respectively for the 12% and 14% groups. This total increased to 1650 grams at 27 weeks of age for the 12% group, the time of the first artificial ejaculations in this particular study. By comparison, males in natural mating conditions need to mature by ~22 weeks of age for best results. No significant differences in semen volume, testis weights, and spermatozoal concentration among the diets were found, but significantly more males produced semen as a result of abdominal massage on the 12% and 14% CP diets. Although there were no significant differences in body weight among the treatments, the 12% and 14% males did exhibit a generally more consistent body weight gain throughout the breeding period. It is important to note that all the diets used in this and subsequent studies from this laboratory at Auburn University had total lysine as 5.1% to 5.3% of total CP and total methionine + cystine as 75% to 77% of lysine in corn-soy based diets. This was similar to the dietary approach used by our laboratory at North Carolina State University, but may differ somewhat from observed commercial practice where low protein male diets are often not properly balanced. We like to have lysine as 5% of CP and methionine + cystine in the range of 75% to 83% of lysine.

In a recent study from the same laboratory at Auburn University, Zhang et al. (1999) made a comparison of 12% and 16% CP diets from four to 52 weeks of age. As in previous reports, there was a higher percentage males producing semen as a result of artificial ejaculation, but there were again no differences in semen quality or quantity. Given that differences in semen quality or quantity are not usually found as a result of difference in CP intake, one has to question if the reported higher percentage males producing semen as a result of artificial ejaculation is simply an artifact of the semen collection process with birds that may vary in body conformation. This response (percentage males producing semen) seems to consistently take the form of a dose response while all other variables show no such dose response. In the experiment of Zhang et al. (1999), the daily ME allowance was 325 kcal during the breeding period. As shown later, this energy allocation is slightly low. A gradual decline in semen production with increasing age and body weight was observed, irrespective of CP level of the diet. The authors interpreted this to mean that continued body weight gain was necessary to maintain optimal male reproductive function. Continued body weight gain clearly would require appropriate increases in ME allowances as body weight increased.

The extensive French work, led by de Reviers (de Reviers, 1977; de Reviers, 1980; de Reviers and Williams, 1984; de Reviers and Seigneurin, 1990) showed that heavy weight line males exhibit greater problems with persistency of testes size and semen production when compared to medium weight male lines. Photostimulation of heavy weight line males typically result in a robust, but short, response in testicular weight and semen production while medium weight male lines exhibit better persistency of these traits. It is presumed, as no nutritional data were given in these reports, that both male lines were fed typical low-density diets. It is further presumed that these diets may have been marginal for the heavy line males, based upon calculations from North Carolina State University data, in a manner similar to that shown in Figure 1 above for quail (Lilburn et al., 1992). The problem of lack of persistency of semen production can be solved, if one is using artificial insemination, by simply not photostimulating the birds and allowing the males to reach sexual maturity at their own pace, presumably after consuming sufficient nutrients.

Therefore, if a bird were deficient in CP during the growing period the effects would be most noticeable around the onset of sexual maturity. Vaughters et al., (1987) fed diets containing 12%, 15%, or 18% from 24 to 27 weeks of age (early breeding period) and reported initial fertility to be highest for the 18% CP diet in natural mating conditions. This suggests a relationship between sexual development and the initiation of reproductive function. Turkey and broiler breeder hens are both known to exhibit an intense desire to mate prior to the onset of egg production. When turkey hens were inseminated during this period of prelay receptivity, there was a significant increase in life-of-flock fertility even in the presence of marginal spermatozoal numbers (McIntyre et al., 1982). This early mating presumably leads to enhanced spermatozoal storage. This may also be true for broiler breeders. It is clear that broiler breeders that exhibit low initial fertility under commercial natural mating conditions, where sexual maturity is needed at about 22 to 24 weeks of age, have difficulty achieving optimum fertility at later ages.

Although there appears to be an impact of CP during the growing period on fertility during the breeding period, dietary CP appears to have less impact during the breeding period. Diets from 5% to 16.9% CP have produced similar results in cages (Arscott and Parker, 1963; Buckner and Savage, 1986; Revington et al., 1991). The reason that these previous workers did not see more differences in fertility due to breeder dietary CP was probably due to the fact that their experiments were often initiated later in the breeder period (after 28 weeks of age). In these experiments, it appears that the birds were not marginal in CP before the experimental diets were applied, which made it difficult to detect fertility differences due to differences in breeder dietary CP. These data also suggest that low protein male feeds should not be used before sexual maturity is complete.

Data from our laboratory suggest the minimum cumulative CP intake required prior to photostimulation for broiler breeder males involved in natural mating to be on the order of 1600 grams, as compared to the 1200 grams required for female. We have found that it is possible to achieve this nutrient target with diets ranging from 12% CP to 17% CP. Moreover, our data, shown below, demonstrate the interaction of body weight and feeding program that influence male reproduction so profoundly. Figure 5 shows the feeding program for a research flock coded as BB-15. The broiler breeders were the Ross 308 package but the data are illustrative of our data with Cobb 500 and Arbor Acres Yield broiler breeder packages as well. All of these birds were reared separately from the females and fed sex-separate during the breeding period.

The combination of feeding program and diet produced an interesting effect on fertility as shown in Figure 6. The concave reared males experienced a decrease in body weight from 40 to 48 weeks of age and this is reflected in the transient decrease in fertility observed in Figure 6 for both the 12% and 17% CP reared males. The effect was more

**Figure 5. Feed per male (g/d) versus weeks of age (1-30 weeks) for males grown separate from females on either a "sigmoid" feed allocation program (Sigmoid) or a "concave" feed allocation program (Concave). Photostimulation was at 23 weeks of age and feeding during the breeding period was initially limited to 110 grams (321 kcal ME) per male per day.**

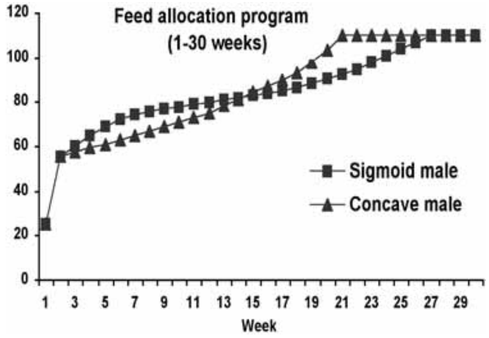
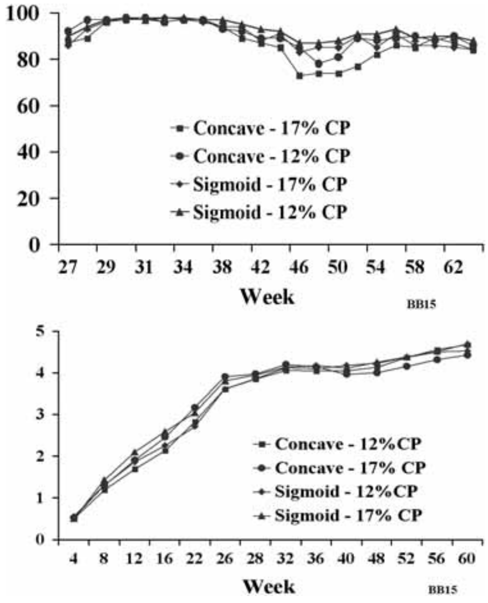


**Figure 6. Fertility of broiler breeder males reared on either a concave or sigmoid feeding program and either a 12% CP or 17% CP diet followed by a 16% CP breeder diet and a constant feed allocation of 110 grams per day to 44 weeks of age. Body weights are shown below.**



pronounced for the 17% CP males that were slightly larger and evidently less resistant to the imposed feeding deficiency. The problem was corrected by a five grams increase in daily feed allocation for the males. The cumulative intake of nutrients at 21 weeks of age were 1568 g CP and 36,593 kcal ME for the 12% males and 2123 g CP and 36,593 house was at 23 weeks of age. Again, the data suggest that if the minimum nutrition is adequate, it is not important what dietary protein level is used to achieve the goal. The males with the most consistent body weight gains produced the best fertility.

## Body Weight In Broiler Breeder Males

It has long been clear that feed restriction to control body weight is both obligatory and beneficial in broiler breeders. However, excessive feed restriction of males during part or all of the growing period has been associated with decreased early fertility (Lilburn et al., 1990). Based upon the discussion above, it is thought that this effect is due to insufficient cumulative nutrition at photostimulation.

The major impetus for sex-separate feeding during the breeding period was the observation that poor fertility was associated with overweight males (McDaniel and Wilson, 1986; Duncan et al., 1990; Fontana et al., 1990; Mauldin, 1992) and separate feeding was believed to be necessary to control male body weight. However, caged males fed near ad libitum are known to exhibit excellent spermatozoal production (Parker and Arscott, 1964; Sexton et al., 1989a). This suggests that an appropriately controlled feed allocation rather than severe restriction is required. It is likely that overly severe feed restriction has actually caused fertility problems due to reduced mating activity as a result of caloric deficiencies. This may help explain the observations of Hocking (1990) who performed experiments with males in floor pens with natural mating during the breeding period. He found a curvilinear relationship between body weight and fertility. This implied that if body weight were too low or too high there would not be optimum fertility. He observed that underweight males were not physiologically sufficient while overweight males often were physically incapable of completing the mating process. He suggested an optimum body weight for optimum fertility that changed with age. He concluded that restricted control of body weight should allow an increase in body weight with age of the male.

We conducted a study to examine this inconsistency. We found that a decrease in fertility coincided with a decrease in female feed allocation and an increase in male body weight in situations where males were fed with females. In a similar manner, a decrease in male feed allocation in situations where males and females were fed separately caused a transient decrease followed by an increase in male body weight coincident with a decrease in fertility. Thereafter, fertility again increased when the feed allocation was increased in the separate-fed males. Male body weight was better controlled and fertility improved when the male feed allocation was increased slowly rather than decreased.

Another interesting study is summarized in Table 3 where groups of males in floor pens (without females) were fed various amounts of feed from 25 to 48 weeks of age. As shown in Table 3, the males that consumed the most feed had the lowest body weights. This is consistent with other data where increasing feed actually did a better job of controlling body weight than did decreasing feed.

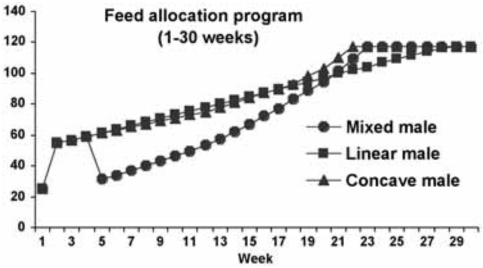
**Table 3. The effect of daily energy intake from 25 to 48 weeks of age on broiler breeder male body weight at 48 weeks of age**

| | Daily metabolizable energy intake (kcal) from 25 to 48 weeks | | | |
|---|---|---|---|---|
| | 314 | 333 | 356 | 371 |
| Body weight (kg) | 5.20 | 4.87 | 4.43 | 4.31 |

What can be the explanation for the paradox shown above? As an example, a typical male at ~30 weeks of age will weigh ~4.00 kg (8.8 lbs.). The daily maintenance requirement at ~21°C (70°F) is ~306 kcal while that of a 4.45 kg (9.8 lbs.) male at ~45 weeks of age would be ~329 kcal. Unless there has been an increase in daily feed allocation proportionate with the body weight gain, the 4.45 kg male would have to exhibit negative growth (lose body weight) as the male mobilized body reserves to make up the energy deficiency. This would continue until the energy reserves of the larger male were exhausted. At this time, mating activity would decrease as testosterone levels decreased. The male would then gain body weight because of inactivity. This could lead one to conclude that males do not necessarily cease mating because they gain excessive body weight, but that males gain excessive body weight because they cease mating!

In the same way that our best egg production occurs when the females slowly gain body weight, our best fertility occurs when the males slowly gain body weight. As the male does not exhibit a decline in daily energy requirement as does the female (due to decreasing egg production) it is suggested that the daily feed allocation be increased at least one gram every three to four weeks during the breeding period such that the male body weight increases slowly but consistently and remains within limits established by practical experience and known to be associated with good fertility. Ken Krueger (1977) found that male turkey semen production could be maximized for the entire life cycle by maintaining the toms on a feeding regimen that supported a consistent weekly body weight gain. Any loss in body weight was associated with a decline in semen production.

**Figure 7. Feed per male (g/bird/day) versus weeks of age (1-30 weeks) for males grown intermingled with females (Mixed), and males grown separate from females on either a "linear" feed allocation program or a "concave" feed allocation program.**



## Broiler Breeder Male Mortality

The mortality of "yield-type" broiler breeder males during the laying period has become a costly problem for the USA poultry industry. The average male mortality from 22 to 64 weeks during the years 1995 to 1999 was approximately 43% (AgriStats, Inc., 6510 Mutual Drive, Fort Wayne, IN 46825). The cause of the majority of this mortality is unknown. To test a theory about the cause of this high mortality, Ross 308 females and non-dubbed Ross males were raised sex-separate on either a "linear" or a "concave" feed allocation program. One group of males was reared with females on a "mixed" program. Birds were grown on a daily 8-hour light and 16 hour dark lighting program and both feed and water were controlled. At the end of 21 weeks, the birds were moved to a curtain-sided laying house and photostimulated. There were the three male treatments shown in Figure 7. "Linear" grown males received constant feed increases of 2.4 g per male/week from four to 28 weeks. After 28 weeks, males received a constant feed amount of 117 g (342 kcal ME) per bird (7 g more than used in Figure 5). All separate grown males received the same amount of cumulative feed through 21 weeks that resulted in a cumulative CP intake of 1600 g and a cumulative ME intake of 32,000 kcal per male at photostimulation at 21 weeks of age.

**Table 4. Body weights of males grown "mixed" with females or grown separate from females on a "linear" or "concave" feed allocation program as in Figure 7.**

| | Male body weight (kg) | | | | | | |
|---|---|---|---|---|---|---|---|
| Male treatment | 12 weeks | 16 weeks | 22 weeks | 26 weeks | 28 weeks | 40 weeks | 52 weeks |
| Mixed | $1.4^c$ | $2.0^c$ | 3.2 | 3.8 | 3.9 | 4.3 | 4.6 |
| Linear | $1.9^a$ | $2.3^a$ | 3.1 | 3.8 | 4.0 | 4.3 | 4.7 |
| Concave | $1.8^b$ | $2.2^b$ | 3.1 | 3.7 | 4.0 | 4.3 | 4.6 |

*a-c Means with different superscripts within columns differ significantly P < 0.05.*

Table 4 displays the male body weights. Males grown intermingled (mixed) with females had significantly lower body weights at 12 and 16 weeks when compared to the separately grown males. Separately grown males on the "linear" program had significantly higher body weights than separately grown males on the "concave" program. However, there were no differences in body weight due to treatment after photostimulation (22 weeks). All males had similar body weights at 22, 26, 28, 40, and 52 weeks of age. Table 5 displays the percentage male mortality. During the early breeder period (22-29 weeks), mortality in the two groups of separately grown males was similar. It appeared that the "mixed" grown males had less mortality during this period although these differences were not statistically significant. Males grown separately on the "linear" program or "mixed" with females had significantly higher mortality from 30 to 44 weeks when compared to males grown separately on the "concave" program. From 45 to 64 weeks, "linear" males numerically had the highest mortality with "mixed" and "concave" males having similar mortality. When mortality was compared from 30 to 64 weeks, "concave" males had significantly lower mortality when compared with the "linear" males. "Mixed" males were intermediate. This same trend was observed overall (22-64 weeks). All data indicated that males grown on a "linear" feed allocation program exhibited higher mortality than males grown on a "concave" feed allocation program. It appears that the majority of the mortality due to "linear" feeding can be expected to occur between 30 to 44 weeks of age.

**Table 5. Percentage male mortality of males grown “mixed” with females or grown separate from females on either a “linear” or “concave” feed allocation program as in Figure 7.**

| | Male mortality (%) | | | | |
|---|---|---|---|---|---|
| Male treatment | 22-29 weeks | 30-44 weeks | 45-64 weeks | 30-64 weeks | 22-64 weeks |
| Mixed | 3.8 | 17.5$^{a}$ | 8.7 | 26.2$^{ab}$ | 30.0$^{xy}$ |
| Linear | 8.7 | 17.5$^{a}$ | 13.8 | 31.3$^{a}$ | 40.0$^{x}$ |
| Concave | 7.5 | 10.0$^{b}$ | 7.5 | 17.5$^{b}$ | 25.0$^{y}$ |

$^{a,b}$ *Means with different superscripts within columns differ significantly ($P < 0.05$).*

$^{x,y}$ *Means with different superscripts within columns differ significantly ($P < 0.10$).*

It appeared that 117 g of feed (342 kcal ME) per male per day was adequate to keep males grown on a 17% CP diet slowly gaining weight from 28 to 60 weeks of age under our current research management that utilizes strict male and female exclusion grills. Fertility was excellent with these males. However, under commercial conditions, a gradual increase in male feed allocation would be advised. Therefore, it appears that the feed allocation program used during the growing period in association with the time of photostimulation can influence broiler breeder male mortality. It appears that this occurs irrespective of body weight. The various groups of males employed in these experiments exhibited average body weights that were not remarkably different. Thus, one can conclude that management of feeding programs should take limited precedence over body weight management.

## Overview Of Separate Male Rearing

Males may successfully be reared separately from females throughout the growing period. Careful attention to the feeding program must be exercised as demonstrated by the field observations outlined below. There has been much discussion about optimum male BW at four and 20 weeks of age. Table 6 shows the relationship between BW and peak hatchability from a commercial company experiencing a fertility problem. Inspection of Table 6 shows little relationship between BW and hatchability, but a graphical summary of the various feeding programs, irrespective of BW, used to grow these males revealed a clear relationship between feeding program and peak hatchability (Figure 8). A thorough examination of all available data suggest a minimum required cumulative nutrient intake from day old to photostimulation of ~1600 g CP and ~32,000 kcal ME per male and a specific feeding program approach is required to minimize mortality and maximize fertility.

## Conclusion

We can conclude that the amount of nutrients a bird has available throughout its life impacts fertility and egg production. Metabolizable energy (or feed allocation) available to the bird during the breeding period is directly correlated to fertility, egg production and body weight. Protein accumulated in the bird during rearing influences the age of sexual maturity and the level of initial fertility for both males and females. Dietary CP has the largest impact during the grower and prebreeder periods, as this is when most of the CP required for initial sexual development is accumulated. Body weight and house temperature need to be controlled within certain limits throughout the life of the flock, however

**Table 6. Relationship between male body weight at 4 and 20 weeks of age and peak hatchability[1]**

| Body weight @ 4 wk (g) | Peak hatch (%) | Body weight @ 20 wk (g) | Peak hatch (%) |
|---|---|---|---|
| 400 – 499 | 85.9 | < 2600 | 85.3 |
| 500 – 599 | 86.7 | 2600 – 2700 | 86.2 |
| 600 – 699 | 85.0 | 2700 – 2800 | 84.7 |
| 700 – 799 | 86.3 | 2800 – 2900 | 86.2 |
| 800 – 899 | 85.1 | 2900 – 3000 | 88.4 |
| 900 – 1000 | 89.7 | > 3000 | 87.4 |

[1] *Based on over 150,000 birds in 19 flocks.*

**Figure 7. Feed per male ((g/bird/day) versus weeks of age (1-30 weeks) for males grown intermingled with females (Mixed), and males grown separate from females on either a “linear” feed allocation program or a “concave” feed allocation program.**

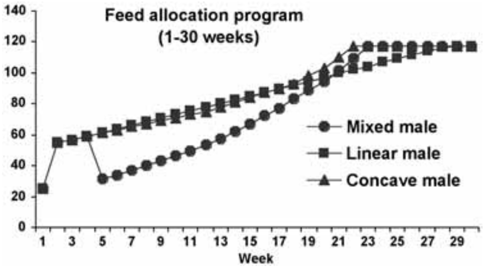
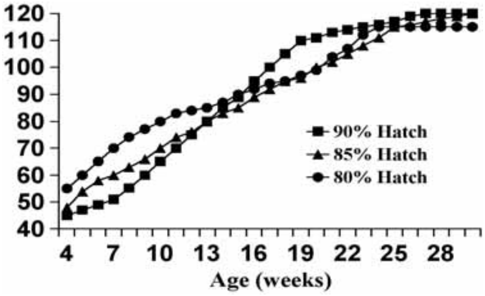


**Figure 8. Graphical representation of feeding programs for males shown in Table 6 that clearly shows a relationship between feeding program and peak hatchability that could not be seen when examining BW alone.**



temperature and body weight management is most critical late in the breeding period because body weight is greatest at this time. The data clearly show that no specific diet has more or less utility for a male broiler breeder. Diets ranging from 12% CP to 17% CP can be fed provided that the cumulative intake of CP to photostimulation is sufficient to support initial sexual development. However, it is clear from practical experience that changing from a moderate or high CP feed to a low CP feed prior to sexual maturity has adverse effects on broiler breeder fertility. It is most important to maintain consistent body weight gain throughout the life of the broiler breeder. Abrupt increases or decreases in body weight are clearly associated with changes in fertility and egg production. This infers a need to closely align ME intake to maintenance requirements that are driven by body weight and temperature. In summary, all the rules for the "standard" broiler breeder remain basically true, but more attention must be paid to these details. The most obvious exception to the basic rules is that excessive "fleshing" can be detrimental in the yield-type female because it can increase sensitivity to environmental temperature, reduce egg production and appetite, and increase mortality.

## Special Notes And Acknowledgements

Some estimates of metabolic energy requirements in the text were based upon the formulas of G. F. Combs, 1968, page 86 in the Proceedings of the Maryland Nutrition Conference for Feed Manufacturers. These estimates have been found to be reasonably accurate, but may need to be adjusted slightly for strain and age effects and should be used with some caution. Portions of this manuscript were excerpted from the Proceedings of the Poultry Beyond 2005 Conference held in Rotorua, New Zealand in February 2001 and from the Proceedings of the Australian Poultry Science Symposium held in Sydney in February 2001.

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# Calculation Of Metabolizable Energy Requirements For The Broiler Breeder Production Period (Part II)

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The daily metabolizable energy requirements for broiler breeders are dependent upon maintenance, growth, and egg production. The following guide provides basic formulas for estimation of each. It is reasonable to assume that these numbers are most reliable when birds are receiving feed daily. The original calculations were based on birds receiving relatively unlimited access to feed and the effect of feed restriction is not fully known. Calculation of daily maintenance requirements involves a fractional exponent so the attached table is provided for ease of reference. Daily average temperature fluctuations must also be accounted for and the attached table is so configured. For example purposes the lower end of the thermoneutral zone (65°F/18.3°C) is used as a base temperature to demonstrate a reasonable maximum daily maintenance requirement. Most houses are operated in the thermoneutral zone (65°F to 85°F/18.3°C to 29.4°C) and little adjustment is needed within this range. However, it should be noted that in breeder houses with high speed air movement the "effective temperature" for the bird may be less than the observed dry bulb temperature due to the effect of "wind chill."

## Maintenance

1.45 $BW^{0.653}$ x CF where body weight (BW) is in grams and CF is a correction factor for average house temperature calculated as CF = 1.78 - 0.012 T where T is average house temperature in °F. The CF = 1 at 65°F/18.3°C. The attached table compensates for certain temperatures.

## Growth

Each gram of growth requires 3.13 kcal ME. This is equivalent to 14.21 kcal per 0.01 pound of gain (0.01 x 454 g/lbs. = 4.54 x 3.13 = 14.21).

## Egg Mass

This is best calculated on a gram basis by first determining egg mass per day and then multiplying by 3.15 kcal.

*Calculations based upon:*
*Combs, G. F., 1968. Proceedings Maryland Nutrition Conference for Feed Manufacturers*

## Example

### *Maintenance Requirement*

Formula A: (1.45 BW0.653) x CF where BW is in grams and CF is a correction factor for average house temperature. The CF may be calculated as CF = 1.78 - 0.012 T where T is average house temperature in °F. The CF = 1 at 65°F/18.3°C. The table lists the maintenance requirements for various body weights and house temperatures.

Example 1: 3400 g (7.495 lbs.) = 293 kcal (~30 weeks) at 65°F/18.3°C

Example 2: 3100 g (6.834 lbs.) = 276 kcal (~28 weeks) at 65°F/18.3°C

### *Growth Requirement*

Formula B: Body weight gain (grams) per day x 3.13 kcal ME per day
Body weight gain (0.1 lbs.) per day x 14.21 kcal ME per day

For a 14-day period from 28 to 32 weeks of age (metric and English units)

Example 3: 3400 g - 3100 g = 300 g ÷ 28 days = 10.7 grams gain per day
10.7 grams x 3.13 kcal/gram gain = 33.5 kcal ME per day

Example 4: 7.495 lbs. - 6.834 lbs. = 0.661 lbs. ÷ 28 days = 0.024 lbs.
2.4 (hundredths of a pound) x 14.21 = 34 kcal ME per day

### *Egg Mass Requirement*

Formula C: Percentage lay x average egg weight (grams) =
average daily egg mass per hen (grams)

Example 5: 80% lay of 53 g eggs
0.80 x 53 g = 42.4 g egg mass per day

Example 6: 85% lay of 52 g eggs
0.85 x 52 g = 44.2 g egg mass per day

Formula D: Egg mass (grams per day) x 3.15 kcal ME per day

Example 7: (From Example 5) 42.4 g x 3.15 = 133.6 kcal ME per day

Example 8: (From Example 6) 44.2 g x 3.15 = 139.2 kcal ME per day

### *Total Daily Metabolizable Energy Required*

Scenario 1: Example 2 + Example 3 + Example 7
276 + 33.5 + 133.6 = 443.1 kcal ME per day

Scenario 2: Example 1 + Example 3 + Example 8
293 + 33.5 + 139.2 = 465.7 kcal ME per day

### *Calculation Of Daily Feed Requirement At Peak*

Scenario 1: Using diets with 2.75, 2.86, or 2.92 kcal ME/g (metric units)
443.1 ÷ 2.75 = 161.1 grams per hen per day
443.1 ÷ 2.86 = 154.9 grams per hen per day
443.1 ÷ 2.92 = 151.7 grams per hen per day

Scenario 2: Using diets with 1250, 1300, or 1327 kcal ME/g (English units)
465.7 ÷ 1250 = 0.373 lbs. per hen per day
465.7 ÷ 1300 = 0.358 lbs. per hen per day
465.7 ÷ 1327 = 0.352 lbs. per hen per day

Obviously, there can be considerable variation due to body weight, egg weight, and temperature. It is important to maintain a relatively stable house temperature. The objective of these calculations is to make a reasonable estimate of the total daily energy required and provide this to the hens in advance of maximum need. This allows the hens to build nutrient reserves that can be utilized if egg production, egg weight, or body weight is greater than anticipated. This will negate the need for "challenge feeding." These reserves also anticipate the increased needs required for peak egg mass that occurs after peak egg production. If the daily ME required for 85% production of 52 gram eggs is 139.2 kcal (Examples 6 and 8) then that required for the egg mass peak might be 0.83 x 58 grams = 48.1 grams x 3.13 = 150.6 kcal. This represents a daily increase of 11.4 kcal. However, this is not an important consideration as daily body weight gain will have decreased and body reserves are available for utilization. It is more important to begin to again look at body weight control as soon as the rate of lay peaks.

| Body Weight | | Daily Average House Temperature (F / C) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 55 / 12.8 | 60 / 15.6 | 65 / 18.3 | 70 / 21.1 | 75 / 23.9 | 80 / 26.7 | 85 / 29.4 |
| pounds | grams | kcal metabolizable energy / day | | | | | | |
| 0.25 | 114 | 36 | 34 | 32 | 30 | 28 | 26 | 24 |
| 0.50 | 227 | 56 | 53 | 50 | 47 | 44 | 41 | 38 |
| 0.75 | 341 | 73 | 69 | 65 | 61 | 57 | 54 | 50 |
| 1.00 | 454 | 88 | 84 | 79 | 74 | 69 | 65 | 60 |
| 1.25 | 568 | 102 | 97 | 91 | 86 | 80 | 75 | 69 |
| 1.50 | 681 | 115 | 109 | 103 | 97 | 90 | 84 | 78 |
| 1.75 | 795 | 127 | 120 | 114 | 107 | 100 | 93 | 86 |
| 2.00 | 908 | 139 | 131 | 124 | 116 | 109 | 102 | 94 |
| 2.25 | 1022 | 150 | 142 | 134 | 126 | 118 | 110 | 102 |
| 2.50 | 1135 | 161 | 152 | 143 | 135 | 126 | 118 | 109 |
| 2.75 | 1249 | 171 | 162 | 153 | 143 | 134 | 125 | 116 |
| 3.00 | 1362 | 181 | 171 | 161 | 152 | 142 | 132 | 123 |
| 3.25 | 1476 | 191 | 180 | 170 | 160 | 150 | 139 | 129 |
| 3.50 | 1589 | 200 | 189 | 179 | 168 | 157 | 146 | 136 |
| 3.75 | 1703 | 209 | 198 | 187 | 176 | 164 | 153 | 142 |
| 4.00 | 1816 | 218 | 206 | 195 | 183 | 171 | 160 | 148 |
| 4.25 | 1930 | 227 | 215 | 203 | 190 | 178 | 166 | 154 |
| 4.50 | 2043 | 236 | 223 | 210 | 198 | 185 | 172 | 160 |
| 4.75 | 2157 | 244 | 231 | 218 | 205 | 192 | 179 | 166 |
| 5.00 | 2270 | 252 | 239 | 225 | 212 | 198 | 185 | 171 |
| 5.25 | 2384 | 261 | 247 | 233 | 219 | 205 | 191 | 177 |
| 5.50 | 2497 | 269 | 254 | 240 | 225 | 211 | 197 | 182 |
| 5.75 | 2611 | 277 | 262 | 247 | 232 | 217 | 202 | 188 |
| 6.00 | 2724 | 284 | 269 | 254 | 239 | 223 | 208 | 193 |
| 6.25 | 2838 | 292 | 276 | 261 | 245 | 229 | 214 | 198 |
| 6.50 | 2951 | 300 | 284 | 267 | 251 | 235 | 219 | 203 |
| 6.75 | 3065 | 307 | 291 | 274 | 258 | 241 | 225 | 208 |
| 7.00 | 3178 | 314 | 298 | 281 | 264 | 247 | 230 | 213 |
| 7.25 | 3292 | 322 | 304 | 287 | 270 | 253 | 236 | 218 |
| 7.50 | 3405 | 329 | 311 | 294 | 276 | 258 | 241 | 223 |
| 7.75 | 3519 | 336 | 318 | 300 | 282 | 264 | 246 | 228 |
| 8.00 | 3632 | 343 | 325 | 306 | 288 | 270 | 251 | 233 |
| 8.25 | 3746 | 350 | 331 | 313 | 294 | 275 | 256 | 238 |
| 8.50 | 3859 | 357 | 338 | 319 | 300 | 280 | 261 | 242 |
| 8.75 | 3973 | 364 | 344 | 325 | 305 | 286 | 266 | 247 |
| 9.00 | 4086 | 370 | 351 | 331 | 311 | 291 | 271 | 251 |
| 9.25 | 4200 | 377 | 357 | 337 | 317 | 296 | 276 | 256 |
| 9.50 | 4313 | 384 | 363 | 343 | 322 | 302 | 281 | 260 |
| 9.75 | 4427 | 390 | 369 | 349 | 328 | 307 | 286 | 265 |
| 10.00 | 4540 | 397 | 376 | 354 | 333 | 312 | 291 | 269 |
| 10.25 | 4654 | 403 | 382 | 360 | 338 | 317 | 295 | 274 |
| 10.50 | 4767 | 410 | 388 | 366 | 344 | 322 | 300 | 278 |
| 10.75 | 4881 | 416 | 394 | 371 | 349 | 327 | 305 | 282 |
| 11.00 | 4994 | 422 | 400 | 377 | 354 | 332 | 309 | 287 |
| 11.25 | 5108 | 429 | 406 | 383 | 360 | 337 | 314 | 291 |
| 11.50 | 5221 | 435 | 411 | 388 | 365 | 342 | 318 | 295 |
| 11.75 | 5335 | 441 | 417 | 394 | 370 | 346 | 323 | 299 |
| 12.00 | 5448 | 447 | 423 | 399 | 375 | 351 | 327 | 303 |
| 12.25 | 5562 | 453 | 429 | 405 | 380 | 356 | 332 | 307 |
| 12.50 | 5675 | 459 | 435 | 410 | 385 | 361 | 336 | 312 |
| 12.75 | 5789 | 465 | 440 | 415 | 390 | 365 | 341 | 316 |
| 13.00 | 5902 | 471 | 446 | 421 | 395 | 370 | 345 | 320 |

*Based upon Combs, G.F., 1968. Page 86 in Proceedings Maryland Nutrition Conference for Feed Manufacturers.*

## Feeding Broiler Breeder Females To Peak Production

At the onset of significant egg production (~5%) the diet should be changed to a breeder feed containing 2.7 – 3.0% calcium, depending upon circumstances. For some strains the use of the high calcium feed before the onset of egg production will cause higher mortality due to sudden death and peritonitis. Feed should be increased in accordance with egg production so that the hens are neither deficient nor fed in excess. Two suggested approaches are shown below where maximum feed allocation is reached at ~70% egg production. This time is selected as it is ~1-2 weeks prior to peak egg production and closely follows the last photoperiod increase that should normally occur at ~50% rate of lay. With "yield" females it is very important to increase the feed slowly. This will minimize mortality and prevent excessive breast meat development ("fleshing") that will cause birds to consume feed slowly and exhibit poor peak production. The two approaches are either proportional to egg production increases or adjusted to give the feed a little more slowly initially to compensate for the fact that some hens start egg production later. The hens that initiate egg production later should not be overfed for best results. Peak daily feed should typically be about 164 grams (36 lbs./100) (164 g x 2.85 kcal ME/g (1295 kcal ME/lbs.) feed = ~467 kcal ME) per bird. For a flock consuming 118 g per bird (26 lbs./100) at 5% production and peak feed is reached at ~70% production then calculations similar to the following are made.

Examples: 164 g – 118 g = 46 g ÷ 13 = 3.54 (rounded off to 3.5) or 36 lbs./100 – 26 lbs./100 = 10 lbs./100 ÷ 13 = ~0.8 lbs./100. The thirteen (13) in the calculation represents the number of feed increases to be given for each 5% increase in egg production.

| Egg Production (%) | Production Feed Increase (#) | Proportional Feed Amount (g) | Proportional Feed Amount (lbs./100) | Adjusted Feed Amount (g) | Adjusted Feed Amount (lbs./100) |
|---|---|---|---|---|---|
| 5 | | 118 | 26.0 | 118 | 26.0 |
| 10 | 1 | 121.5 | 25.8 | 120 | 26.4 |
| 15 | 2 | 125 | 26.6 | 122 | 26.9 |
| 20 | 3 | 128.5 | 27.4 | 124 | 27.3 |
| 25 | 4 | 132 | 28.2 | 126 | 27.8 |
| 30 | 5 | 135.5 | 30.0 | 129 | 28.4 |
| 35 | 6 | 139 | 30.8 | 132 | 29.1 |
| 40 | 7 | 142.5 | 31.6 | 136 | 30.0 |
| 45 | 8 | 146 | 32.4 | 140.5 | 30.9 |
| 50 | 9 | 149.5 | 33.2 | 145 | 31.9 |
| 55 | 10 | 153 | 34.0 | 149.5 | 32.9 |
| 60 | 11 | 156.5 | 34.8 | 154 | 33.9 |
| 65 | 12 | 160 | 35.6 | 159 | 35.0 |
| 70 | 13 | 164* | 36.0* | 164 | 36.0 |

** The last increases makes up the difference due to rounding errors.*

The above program will provide a feed increase every two to three days as egg production increases. Once some experience is gained with the approach outlined above it is possible to develop a daily feed increase program, based upon records of previous flock feeding programs, that will simply give small increases every day beginning at 5% rate of lay. This will help avoid calculations and possible confusion. Daily feed increases as egg production increases will also help prevent mortality and excessive body weight gain. Practical experience teaches that this daily feed increase can be about 0.40 lbs./100 or 2 gram per bird per day, assuming that egg production increases normally. Again, it may be beneficial to begin with smaller daily feed increases and increase the daily increment as the number of birds in lay increases. It should be remembered that 25% egg production means that 25% of the flock is in production while 75% of the flock is still not in lay. Excessive feed increases for the hens not yet in lay may lead to excessive fleshing and higher than normal mortality.

The selection of the peak feed amount should be based upon a careful analysis of body weight, body weight gain, egg production, egg weight, dietary metabolizable energy content, and environmental temperature. Daily metabolizable energy needs for maintenance, growth, and egg mass demand the predominant consideration. Please refer to another guide for assistance in calculation of metabolizable energy requirements during the egg production period. The practice of providing feed slightly in excess of requirements at peak egg production, as outlined above, is similar to "challenge" feeding practiced by many broiler breeder managers. With the approach outlined above, feed decreases may begin promptly once the birds reach peak production without concern about a loss of egg production.

## Feeding Broiler Breeder Females After Peak Production

Female body weight will exhibit an increase 2 to 4 weeks after peak egg production (when peak production is expressed on a percentage, not egg mass, basis) is reached if care is not taken to readjust feed allocation in a timely manner. This body weight increase is most often caused by failure to promptly reduce feed intake to a level commensurate with requirements. However, as it is often wise to provide a peak feed amount that is greater than absolutely needed ("challenge feeding") in order to be certain that all the birds have sufficient nutrients. It is important to remove this excess feed and continue to decrease feed as the flock ages and egg production decreases to help control female body weight. Adequacy of the feed reduction program can be judged by careful and regular monitoring of breast meat ("fleshing") and fat pad to be sure that abrupt changes or excessive losses do not occur. It is desirable to have hens that have an obvious fat pad. It is also important to monitor the flock for normal declines in egg production. Evidence of hens becoming broody at peak is an indication of insufficient peak feed. Initiating molt later in the laying cycle is an indicator of insufficient feed or excessively rapid feed withdrawal for existing conditions (peak feed and weather). A suggested approach is outlined below.

Step 1. Reach ~164 grams of feed (465-475 kcal ME) per hen per day (~36 lbs./100) at ~70% rate of lay.
Step 2. After 5 days at a consistent rate of lay near 80% or greater reduce feed by ~5 grams per hen per day to ~159 grams per hen per day (~35 lbs./100). This will be about 30-32 weeks of age. This initial reduction may need to be less than suggested if the peak feed amount is less than suggested or if the house temperature is cold.
Step 3. Decrease feed 1 gram (0.2 lbs./100) per week until 40 weeks of age. As an example, the feed allocation will reach about 150 grams if the peak feed was 164 grams and feed reductions began at 30 weeks of age.
Step 4. Decrease feed 1 gram (0.2 lbs./100) every other week thereafter to 45 weeks.
Step 5. Feed decreases after 45 weeks of age are optional dependent upon weather and body weight. A very slow monthly reduction is advisable to adjust for declining egg production. It is typical for total feed reduction to be in the range of 10% from the peak feed amount, depending upon how much the peak feed was relative to actual requirement. For a 164 gram peak feed allocation the 10% reduction amount will be 148 grams.

Examine the weekly egg production and weekly body weight and physical handling data that you collect. If there is evidence that egg production was decreased by the feed decreases in Steps #2 to #4 above you need to increase the peak feed amount or reduce the Step #2 decrease for the next flock and repeat the process of evaluation. If the female body weight increased excessively during the 3 to 6 week period after peak, the feed decreases in Steps #2 and #3 need to be increased and the process of evaluation repeated. If egg production and female body weight react as desired then repeat the program on more flocks while performing the above evaluation. Over a period of time, finalize the program with predetermined variations planned for seasonal differences in temperature. Feed should be decreased more rapidly in hot weather than in cold weather. With the onset of cold weather it may be necessary to increase the feed amount.

It is common practice to employ a late (second phase) breeder period diet that has a reduced level of protein and increased level of calcium. As dietary protein intake may influence albumen quality and egg shell quality the use of a lower protein late phase breeder feed must be approached cautiously. Further, excessive calcium intake may strengthen the eggshell by increasing shell thickness but may also result in the closure of some eggshell pores with a negative impact on hatchability. The use of ascorbic acid (Vitamin C) is beneficial in older flocks as it improves albumen and eggshell quality without creating excessively thick shells.

## Estimation Of Required Feed Allocations During Rearing And Reproductive Tract Development

For weekly body weight gains of the following amounts the daily feed allocation contains a portion for body weight gain (in addition to amount for maintenance that can be calculated with aid of another guide) approximately as calculated below, assuming diets containing 1325 kcal ME/lbs. (2.915 kcal ME/g)

0.15 lbs. (68.1 g) gain per week
0.15 x 454 g/lbs. x 3.13 kcal/g ÷'d6 7 = 30.45 kcal ME per day or 2.30 lbs./100 (10.44 g/day)

0.20 lbs. (90.8 g) gain per week
0.20 x 454 g/lbs. x 3.13 kcal/g ÷'d6 7 = 40.60 kcal ME per day or 3.06 lbs./100 (13.89 g/day)

0.25 lbs. (113.5 g) gain per week
0.25 x 454 g/lbs. x 3.13 kcal/g ÷'d6 7 = 50.75 kcal ME per day or 3.83 lbs./100 (17.39 g/day)

| Body Weight | | Maintenance @65ºF/18.3ºC | | Weekly Gain | | Total kcal | Feed @1325 kcal ME /lbs. (2.915 kcal/g) | |
|---|---|---|---|---|---|---|---|---|
| lbs | g | (kcal ME) | (Feed lbs.) | (lbs.) | (kcal) | | (lbs./100) | (g) |
| 1 | 454 | 79 | 5.96 | 0.15 | 30.45 | 109.45 | 8.26 | 37.5 |
| 2 | 908 | 124 | 9.36 | 0.15 | 30.45 | 154.45 | 11.66 | 52.9 |
| | | | | 0.20 | 40.60 | 164.60 | 12.42 | 56.4 |
| 3 | 1362 | 161 | 12.15 | 0.15 | 30.45 | 191.45 | 14.45 | 65.6 |
| | | | | 0.20 | 40.60 | 201.60 | 15.22 | 69.1 |
| | | | | 0.25 | 50.75 | 211.75 | 15.98 | 72.5 |
| 4 | 1816 | 195 | 14.72 | 0.15 | 30.45 | 225.45 | 17.02 | 77.3 |
| | | | | 0.20 | 40.60 | 235.60 | 17.78 | 80.7 |
| | | | | 0.25 | 50.75 | 245.75 | 18.55 | 84.2 |
| 5 | 2270 | 225 | 16.98 | 0.20 | 40.60 | 265.60 | 20.05 | 91.0 |
| | | | | 0.25 | 50.75 | 275.75 | 20.81 | 94.5 |
| 6 | 2724 | 254 | 19.17 | 0.20 | 40.60 | 294.60 | 22.23 | 100.9 |
| | | | | 0.25 | 50.75 | 304.75 | 23.00 | 104.4 |

If it is assumed for female broiler breeders that the daily feed allocation will be ~20 lbs./100/day (90 g/day) at 20 weeks of age. If we commence restricted feeding at ~7.0 lbs./100/day (~32 g/day) at 2 weeks of age we can calculate the approximate average weekly feed increase for females for body weight gain alone to be:

20 lbs. – 7.0 lbs. = 13.0 lbs. ÷ 18 increases = 0.722 lbs./100 pullets per week or 3.3 g/pullet per week.

For males we can estimate in a similar manner since the early feed intake is limited and we can calculate the required minimum feed at 6.0 – 7.0 pounds (2.72-3.18 kg) body weight at ~20 weeks of age where we will be feeding about 24 lbs./100/day (109 g/day). In this case we can calculate approximate average weekly feed increase for males for body weight gain alone from 14 lbs./100 (63.6 g/day) fed at 4 weeks of age to be:

24 lbs. - 14 lbs. = 10 lbs. ÷ 16 increases = ~0.63 lbs./100 cockerels per week or 2.84 g/cockerel per week.

In both these cases (males and females) the actual amount of feed required for basic maintenance decreases slightly with age and body weight such that the above general estimates are slightly higher than actually required. As a general rule of thumb, it is suggested that females typically receive approximately 70 grams (15.4 lbs./100) during their 15th week of age.

Given that precision feeding of “yield” females is needed to avoid the problems of overfeeding, but still supply sufficient nutrients for proper reproductive development, an obvious question arises. How much feed (metabolizable energy) is actually needed during the prelay period (photostimulation to first egg on an individual bird basis) for reproductive tract development. In other words, how much body weight gain is really associated with reproductive “bloom” apart from normal body weight gain and maintenance. This can be estimated from the weights of important organs and tissues that develop at the time of sexual maturity following photostimulation under blackout rearing conditions. We can estimate the additional body weight associated with each key organ or tissue at sexual maturity as follows:

| | |
|---|---|
| Ovary | 55 g |
| Oviduct | 55 g |
| Liver | 25 g |
| Fat pad | 35 g |
| | 170 g  454 g/lbs. = 0.374 lbs. of body weight. |

If we assume that, under conditions of blackout rearing, body weight at 21 weeks is 4.6 lbs. (2.09 kg), normal weekly gain is 0.20 lbs. (91 grams), normal weekly feed increase is 4.5 grams, and photostimulation is at 21 weeks (147 days) of age, then the body weight without reproductive tract development will be ~5.4 lbs. (2.45 kg) at 25 weeks of age. If we add the 0.40 lbs. (182 grams) needed for minimal reproductive development, as calculated above, then we have 5.80 lbs. (2.63 kg) at first egg, if that first egg is laid at 25 weeks of age (5% production). This body weight may vary upwards slightly depending upon the feeding program during rearing.

The feed required for reproductive development to the minimum age for onset of lay can be calculated as follows:

170 grams x 3.1 kcal ME/g gain ÷ 2.9 kcal ME/g (1320 kcal ME/lbs.) feed = ~182 grams (0.40 lbs.) of feed.

This calculation assumes that all hens will start to lay at 25 weeks of age. However, it must be remembered that peak feed will not be reached until about 70% hen-day egg production when most hens have started egg production. This will be about 70 days after photostimulation. Providing more feed than is necessary will only result in additional body weight gain and greater "fleshing."

These calculations are shown in a tabular form below.

| | |
|---|---|
| Reproductive gain, g | 170 |
| kcal required/g gain | x 3.1 |
| Total kcal required | 527.0 |
| kcal ME/g feed | ÷2.9 |
| Total feed required, g | 181.7 |
| Days to total onset of lay (70% lay) | ÷70 |
| Feed required per day, g | 2.60 |

***The important point to remember is that the amount of additional feed required for reproductive tract development is relatively small and that this demand comes when the normal demand is slightly decreasing.***

Maximum feed increases in blackout housing for males should never exceed 7 grams per week and 5 grams per week for females prior to photostimulation. After photostimulation, and mixing with females, sexually mature males should have their feed increases limited to about 1 gram per week as a maximum while females should need less than 3.30 + 2.60 = 5.90 g per week. It is suggested that a small additional feed increment (6-7 g for a single week) be given at the time of photostimulation followed by no more than 5 grams per week until 5% rate of lay is reached.

If we give too much feed too fast, we may simply increase body weight, primarily breast meat, and cause reproductive problems such as peritonitis and sudden death. The excess breast meat probably increases maintenance and inhibits reproductive development. This may be why heavy breasts relative to fat pad develop when feed increases are too rapid. The birds with excess breast meat relative to fat pad tend to lay poorly. A conservative feeding approach (minimum shown above) would be advisable until one becomes familiar with the particular strain of broiler breeder in the particular situation. The above guide should be useful in reviewing past flock records to determine why performance varied by flock. To provide some guidance concerning minimum feed requirements for maintenance and growth alone (for the specific male and female body weight programs shown in the examples), charts are available in other guides that show the amount of feed required for males and females at various temperatures and dietary energy combinations. It is also important to have the flock consume sufficient cumulative nutrition prior to photostimulation in order that they are properly prepared to respond to the photostimulation.

Some estimates above based upon G. F. Combs, 1968, page 86 in Proceedings Maryland Nutrition Conference for Feed Manufacturers. These estimates may need to be adjusted slightly for strain, age, and local effects and should be used with some caution.

## Broiler Breeder Flock Management Case Histories

### 1. *Management Of Females*

**Situation:** Results had been mixed during recent years with a general lack of consistency in egg production and hatchability with "Classic Regular Strain" in this company. Experiences with a yield strain had been very disappointing. The general management philosophy had been to follow a body weight management approach. With the use of blackout rearing it had been generally believed that an "in-season" type of body weight standard could be followed.

**Comment:** It is my belief that the real reason for the difference between "in-season" and "out-of-season" birds is environmental temperature. It has been my experience that birds reared in hot weather (out-of-season) will perform poorly if they do not consume the same amount of feed as the birds that are grown in cool weather (in-season). There will be a higher body weight as a result. This is absolutely necessary if the flocks are to consume sufficient feed during rearing to be able to perform optimally during the laying period. I have found that females require about 23,000 kcal ME and 1200 grams of crude protein at 20 weeks of age (140 days) as absolute minimums.

**Field Observations:** By comparison I found that some of the commercial flocks had cumulative ME near 20,000 kcal at 20 weeks of age. It has also been my experience that feed increases between 15 and 25 weeks of age should be in the 5 gram per week range to avoid development of excessive breast meat. Excessive breast meat is associated with slow feed consumption at peak, a typical problem. The only exception to this slow feeding pattern is immediately following photostimulation when a slightly larger feed increase is needed to supply the nutrients required for reproductive development. Following an initial visit and discussion a few houses were placed onto a feeding program rather than a body weight program. The flocks produced peaks of 80% - 84% using the female feeding program outlined below that produced heavier than normal body weights (BW) that are similar to an out-of-season standard rather than an in-season standard.

| | Actual | | Proposed Female Standards | |
|---|---|---|---|---|
| Week | Feed | BW | Feed | BW |
| | (g) | (g) | (g) | (g) |
| 1 | 24 | 120 | 24 | 125 |
| 2 | 30 | 263 | 30 | 265 |
| 3 | 35 | 390 | 35 | 400 |
| 4 | 38 | 523 | 38 | 525 |
| 5 | 41 | 613 | 41 | 625 |
| 6 | 44 | 745 | 44 | 750 |
| 7 | 47 | 839 | 47 | 850 |
| 8 | 50 | 933 | 50 | 950 |
| 9 | 52 | 1034 | 53 | 1040 |
| 10 | 56 | 1106 | 56 | 1120 |
| 11 | 60 | 1159 | 59 | 1200 |
| 12 | 63 | 1277 | 63 | 1300 |
| 13 | 66 | 1403 | 67 | 1400 |
| 14 | 71 | 1583 | 71 | 1590 |
| 15 | 75 | 1655 | 75 | 1680 |
| 16 | 79 | 1737 | 80 | 1770 |
| 17 | 84 | 1861 | 85 | 1860 |
| 18 | 89 | 1992 | 90 | 1990 |
| 19 | 92 | 2106 | 95 | 2130 |
| 20 | 97 | 2267 | 100 | 2280 |
| 21 | 105 | 2334 | 105 | 2350* |
| 22 | 111 | 2490 | 115 | 2500 |
| 23 | 121 | 2669 | 120 | 2675 |
| 24 | 124 | 2875 | 125 | 2875 |
| Cumulative nutrients at 20 weeks of age (based upon 2.75 kcal ME/g and 16% CP diets) | | | | |
| ME (kcal) | | 22,965 | | 23,158 |
| CP (grams) | | 1,336 | | 1,347 |

**Photostimulation suggested at 148 days of age (beginning of 22nd week) with 10 gram increase at lighting as shown above. Do not give the extra feed until the flock is photostimulated and then be certain that the relative weekly feed increases are maintained as indicated above.*

**Comments:** I also show above my suggestions for a Female Feeding and Body Weight Standard to the right. I developed this guide from data from within the company. This proposed body weight standard is to be assumed to be an out-of-season (high side reference) standard for the hotter growing season. The normal in-season (low side reference) standard, for the respective strain, may be used as the minimum BW guide if cool weather growing conditions prevail. I would suggest that both low and high references be posted as part of the records and body weights be generally maintained between these two reference points with an emphasis on the feeding program and achievement of the necessary cumulative nutrient targets.

**Observations:** The feeding program to peak egg production for this flock is shown below along with my suggestions for a revised program that will provide additional peak feed to the flocks, assuming that the flocks will consume the feed, and they will if the breast meat is not excessive. Some of the houses in this flock consumed 161 grams of feed at peak with no problem.

| Actual | | Proposed Standard | |
|---|---|---|---|
| Lay | Feed | Lay | Feed |
| (%) | (g) | (%) | (g) |
| 5 | 130 | 5 | 130 |
| 10 | 132 | 10 | 132 |
| 15 | 134 | 15 | 134 |
| 20 | 136 | 20 | 136 |
| 25 | 138 | 25 | 138 |
| 30 | 140 | 30 | 140 |
| 35 | 142 | 35 | 142 |
| 40 | 145 | 40 | 145 |
| 45 | 148 | 45 | 148 |
| 50 | 151 | 50 | 151 |
| 55 | 154 | 55 | 154 |
| | | 60 | 157 |
| | | 65 | 160 |
| | | 70 | 163 |

Comments: If feed consumption time remains acceptable (less than 3-4 hours) the peak feed may be increased to 166 grams (464 kcal ME) at 75% lay. This can be considered a type of "challenge feeding." This should be followed by an immediate decrease in feed at peak egg production (5 days at similar egg production) to prevent excessive body weight gain following peak production. I should state that I generally overfeed at peak ("challenge feed") to be certain that all birds have sufficient feed to support maximum egg production and then reduce feed quickly to control the female body weight.

## *2. Management Of Males And Females*

**Situation:** This company has had excellent results with some flocks (>160 chicks per hen) and poorer results with other flocks on supposedly the same body weight program and with very good uniformity achieved through a series of “grading” exercises.

**Field Observations:** By comparison among the good and bad flocks for egg production and fertility I found differences in feeding programs as shown in the table below. An important factor in this problem was the fact that the feed before 18 weeks was 2.65 kcal ME/g while the feed after 18 weeks was 2.75 kcal ME/g. This represents the equivalent of a large feed increase in and of itself.

It is very important to keep weekly feed records for the purpose of comparisons such as those shown above.

| Weeks of age | Females | | | Males | | |
|---|---|---|---|---|---|---|
| | II | I | III | II | I | III |
| | Poor | Good | Best | Poor | Good | Best |
| | grams/bird/day | | | grams/bird/day | | |
| 14 | 77.1 | 80.8 | 72.8 | 84.3 | 90.9 | 70.7 |
| 15 | 80.6 | 82.8 | 72.5 | 86.8 | 85.6 | 83.2 |
| 16 | 86.3 | 85.5 | 88.9 | 86.3 | 85.0 | 82.0 |
| 17 | 98.2 | 94.3 | 91.3 | 87.9 | 92.6 | 87.5 |
| 18 | 106.0 | 99.1 | 96.3 | 102.4 | 100.0 | 91.2 |
| 19 | 108.4 | 105.7 | 97.4 | 122.6 | 90.2 | 93.3 |
| 20 | 116.4 | 110.8 | 104.5 | 112.1 | 116.2 | 115.6 |
| 21 | 120,4 | 113.8 | 103.5 | 116.1 | | 107.0 |
| 22 | 128.7 | 121.3 | 117.1 | | | 115.1 |
| 23 | 127.6 | 126.4 | | 126.9 | 110.2 | |
| 24 | 134.6 | 127.3 | | 112.6 | 123.2 | |
| 25 | 148.4 | 136.0 | | 126.2 | 112.6 | |
| 26 | 150.8 | 162.7 | | 129.7 | 115.6 | |
| 27 | 164.1 | 166.6 | | 126.0 | 119.0 | |
| 28 | 166.2 | 168.8 | | 124.1 | 116.5 | |
| 29 | | | | 128.8 | 128.0 | |
| 30 | | | | 135.1 | 123.0 | |

It is important to remember that there was a ME increase from 18 to 19 weeks that acted like a feed increase itself and no large feed increase should have occurred at the same time. The flocks with excessively large feed increases from 15 to 25 weeks seem to have the most difficulties in females. Males that are fed too much feed after mixing with females also seem to have difficulties.

| | | House Temperature | | | House Temperature | | | House Temperature | | | House Temperature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 15.6 | 21.1 | 26.7 | 15.6 | 21.1 | 26.7 | 15.6 | 21.1 | 26.7 | 15.6 | 21.1 | 26.7 |
| BW | BW.653 | Maintenance Kcal | | | Feed amounts for maintenance only (2.81 kcal/g) | | | Feed amounts for maintenance only (2.86 kcal/g) | | | Feed amounts for maintenance only (2.92 kcal/g) | | |
| g | g | kcal | | | g | | | g | | | g | | |
| 100 | 20.23 | 31.1 | 27.6 | 24.1 | 11.07 | 9.81 | 8.56 | 10.87 | 9.64 | 8.41 | 10.65 | 9.44 | 8.24 |
| 200 | 31.81 | 48.9 | 43.4 | 37.8 | 17.40 | 15.43 | 13.46 | 17.10 | 15.16 | 13.22 | 16.74 | 14.85 | 12.95 |
| 300 | 41.45 | 63.7 | 56.5 | 49.3 | 22.67 | 20.11 | 17.54 | 22.28 | 19.76 | 17.23 | 21.82 | 19.35 | 16.88 |
| 400 | 50.02 | 76.9 | 68.2 | 59.5 | 27.36 | 24.26 | 21.17 | 26.88 | 23.84 | 20.80 | 26.33 | 23.35 | 20.37 |
| 500 | 57.87 | 88.9 | 78.9 | 68.8 | 31.65 | 28.07 | 24.49 | 31.10 | 27.58 | 24.06 | 30.46 | 27.01 | 23.56 |
| 600 | 65.18 | 100.2 | 88.8 | 77.5 | 35.65 | 31.62 | 27.58 | 35.03 | 31.06 | 27.10 | 34.31 | 30.43 | 26.54 |
| 700 | 72.09 | 110.8 | 98.3 | 85.7 | 39.43 | 34.97 | 30.50 | 38.74 | 34.35 | 29.97 | 37.94 | 33.65 | 29.35 |
| 800 | 78.65 | 120.9 | 107.2 | 93.5 | 43.02 | 38.15 | 33.28 | 42.27 | 37.48 | 32.70 | 41.40 | 36.71 | 32.03 |
| 900 | 84.94 | 130.6 | 115.8 | 101.0 | 46.46 | 41.20 | 35.94 | 45.65 | 40.48 | 35.31 | 44.71 | 39.65 | 34.59 |
| 1000 | 90.99 | 139.9 | 124.0 | 108.2 | 49.77 | 44.14 | 38.50 | 48.90 | 43.36 | 37.83 | 47.90 | 42.47 | 37.05 |
| 1100 | 96.83 | 148.8 | 132.0 | 115.1 | 52.97 | 46.97 | 40.97 | 52.04 | 46.15 | 40.26 | 50.97 | 45.20 | 39.43 |
| 1200 | 102.50 | 157.5 | 139.7 | 121.9 | 56.06 | 49.72 | 43.37 | 55.08 | 48.85 | 42.61 | 53.95 | 47.84 | 41.74 |
| 1300 | 108.00 | 166.0 | 147.2 | 128.4 | 59.07 | 52.38 | 45.70 | 58.04 | 51.47 | 44.90 | 56.85 | 50.41 | 43.97 |
| 1400 | 113.35 | 174.2 | 154.5 | 134.8 | 62.00 | 54.98 | 47.96 | 60.92 | 54.02 | 47.12 | 59.66 | 52.91 | 46.16 |
| 1500 | 118.57 | 182.2 | 161.6 | 141.0 | 64.86 | 57.51 | 50.17 | 63.72 | 56.51 | 49.30 | 62.41 | 55.35 | 48.28 |

*"Based upon Combs, G.F., 1968. Page 86 in Proceedings Maryland Nutrition Conference for Feed Manufacturers."*

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| | | House Temperature | | | House Temperature | | | House Temperature | | | House Temperature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 15.6 | 21.1 | 26.7 | 15.6 | 21.1 | 26.7 | 15.6 | 21.1 | 26.7 | 15.6 | 21.1 | 26.7 |
| BW | BW.653 | Maintenance Kcal | | | Feed amounts for maintenance only (2.81 kcal/g) | | | Feed amounts for maintenance only (2.86 kcal/g) | | | Feed amounts for maintenance only (2.92 kcal/g) | | |
| g | g | kcal | | | g | | | g | | | g | | |
| 1600 | 123.68 | 190.1 | 168.6 | 147.1 | 67.65 | 59.99 | 52.33 | 66.47 | 58.94 | 51.42 | 65.10 | 57.73 | 50.36 |
| 1700 | 128.67 | 197.8 | 175.4 | 153.0 | 70.38 | 62.41 | 54.45 | 69.15 | 61.32 | 53.49 | 67.73 | 60.06 | 52.39 |
| 1800 | 133.57 | 205.3 | 182.0 | 158.8 | 73.06 | 64.79 | 56.52 | 71.78 | 63.65 | 55.53 | 70.30 | 62.35 | 54.39 |
| 1900 | 138.36 | 212.7 | 188.6 | 164.5 | 75.68 | 67.11 | 58.55 | 74.36 | 65.94 | 57.52 | 72.83 | 64.59 | 56.34 |
| 2000 | 143.08 | 219.9 | 195.0 | 170.1 | 78.26 | 69.40 | 60.54 | 76.89 | 68.19 | 59.48 | 75.31 | 66.79 | 58.26 |
| 2100 | 147.71 | 227.0 | 201.3 | 175.6 | 80.79 | 71.65 | 62.50 | 79.38 | 70.39 | 61.41 | 77.75 | 68.95 | 60.15 |
| 2200 | 152.27 | 234.0 | 207.5 | 181.0 | 83.29 | 73.86 | 64.43 | 81.83 | 72.57 | 63.30 | 80.15 | 71.07 | 62.00 |
| 2300 | 156.75 | 240.9 | 213.7 | 186.4 | 85.74 | 76.03 | 66.33 | 84.24 | 74.70 | 65.17 | 82.51 | 73.17 | 63.83 |
| 2400 | 161.17 | 247.7 | 219.7 | 191.6 | 88.15 | 78.17 | 68.20 | 86.61 | 76.81 | 67.00 | 84.83 | 75.23 | 65.63 |
| 2500 | 165.52 | 254.4 | 225.6 | 196.8 | 90.54 | 80.29 | 70.04 | 88.95 | 78.88 | 68.81 | 87.13 | 77.26 | 67.40 |
| 2600 | 169.82 | 261.0 | 231.5 | 201.9 | 92.88 | 82.37 | 71.85 | 91.26 | 80.93 | 70.60 | 89.39 | 79.27 | 69.15 |
| 2700 | 174.05 | 267.5 | 237.2 | 206.9 | 95.20 | 84.42 | 73.65 | 93.54 | 82.95 | 72.36 | 91.62 | 81.24 | 70.87 |
| 2800 | 178.24 | 273.9 | 242.9 | 211.9 | 97.49 | 86.45 | 75.42 | 95.79 | 84.94 | 74.10 | 93.82 | 83.20 | 72.58 |
| 2900 | 182.37 | 280.3 | 248.6 | 216.8 | 99.75 | 88.46 | 77.17 | 98.01 | 86.91 | 75.82 | 95.99 | 85.13 | 74.26 |
| 3000 | 186.45 | 286.6 | 254.1 | 221.7 | 101.98 | 90.44 | 78.89 | 100.20 | 88.86 | 77.51 | 98.14 | 87.03 | 75.92 |
| 3100 | 190.48 | 292.8 | 259.6 | 226.5 | 104.19 | 92.40 | 80.60 | 102.37 | 90.78 | 79.19 | 100.27 | 88.91 | 77.56 |
| 3200 | 194.47 | 298.9 | 265.1 | 231.2 | 106.37 | 94.33 | 82.29 | 104.51 | 92.68 | 80.85 | 102.37 | 90.78 | 79.19 |
| 3300 | 198.42 | 305.0 | 270.4 | 235.9 | 108.53 | 96.25 | 83.96 | 106.63 | 94.56 | 82.49 | 104.44 | 92.62 | 80.80 |
| 3400 | 202.33 | 311.0 | 275.8 | 240.6 | 110.67 | 98.14 | 85.61 | 108.73 | 96.42 | 84.11 | 106.50 | 94.44 | 82.39 |
| 3500 | 206.19 | 316.9 | 281.0 | 245.2 | 112.78 | 100.02 | 87.25 | 110.81 | 98.27 | 85.72 | 108.53 | 96.25 | 83.96 |
| 3600 | 210.02 | 322.8 | 286.3 | 249.7 | 114.88 | 101.87 | 88.87 | 112.87 | 100.09 | 87.31 | 110.55 | 98.03 | 85.52 |
| 3700 | 213.81 | 328.6 | 291.4 | 254.2 | 116.95 | 103.71 | 90.47 | 114.91 | 101.90 | 88.89 | 112.55 | 99.80 | 87.06 |
| 3800 | 217.57 | 334.4 | 296.5 | 258.7 | 119.01 | 105.53 | 92.06 | 116.92 | 103.69 | 90.45 | 114.52 | 101.56 | 88.59 |
| 3900 | 221.29 | 340.1 | 301.6 | 263.1 | 121.04 | 107.34 | 93.64 | 118.92 | 105.46 | 92.00 | 116.48 | 103.29 | 90.11 |
| 4000 | 224.98 | 345.8 | 306.6 | 267.5 | 123.06 | 109.13 | 95.20 | 120.91 | 107.22 | 93.53 | 118.42 | 105.02 | 91.61 |
| 4100 | 228.64 | 351.4 | 311.6 | 271.9 | 125.06 | 110.90 | 96.74 | 122.87 | 108.96 | 95.05 | 120.35 | 106.72 | 93.10 |
| 4200 | 232.26 | 357.0 | 316.6 | 276.2 | 127.04 | 112.66 | 98.28 | 124.82 | 110.69 | 96.56 | 122.26 | 108.42 | 94.58 |
| 4300 | 235.86 | 362.5 | 321.5 | 280.4 | 129.01 | 114.40 | 99.80 | 126.75 | 112.40 | 98.06 | 124.15 | 110.10 | 96.04 |
| 4400 | 239.43 | 368.0 | 326.3 | 284.7 | 130.96 | 116.14 | 101.31 | 128.67 | 114.10 | 99.54 | 126.03 | 111.76 | 97.49 |
| 4500 | 242.97 | 373.4 | 331.2 | 288.9 | 132.90 | 117.85 | 102.81 | 130.57 | 115.79 | 101.01 | 127.89 | 113.41 | 98.93 |
| 4600 | 246.48 | 378.8 | 336.0 | 293.1 | 134.82 | 119.56 | 104.29 | 132.46 | 117.47 | 102.47 | 129.74 | 115.05 | 100.36 |
| 4700 | 249.97 | 384.2 | 340.7 | 297.2 | 136.72 | 121.25 | 105.77 | 134.33 | 119.13 | 103.92 | 131.57 | 116.68 | 101.78 |
| 4800 | 253.43 | 389.5 | 345.4 | 301.3 | 138.62 | 122.92 | 107.23 | 136.19 | 120.78 | 105.36 | 133.40 | 118.29 | 103.19 |
| 4900 | 256.86 | 394.8 | 350.1 | 305.4 | 140.50 | 124.59 | 108.69 | 138.04 | 122.41 | 106.79 | 135.20 | 119.90 | 104.59 |
| 5000 | 260.27 | 400.0 | 354.8 | 309.5 | 142.36 | 126.25 | 110.13 | 139.87 | 124.04 | 108.20 | 137.00 | 121.49 | 105.98 |
| 5100 | 263.66 | 405.2 | 359.4 | 313.5 | 144.22 | 127.89 | 111.56 | 141.69 | 125.65 | 109.61 | 138.78 | 123.07 | 107.36 |
| 5200 | 267.02 | 410.4 | 364.0 | 317.5 | 146.06 | 129.52 | 112.99 | 143.50 | 127.26 | 111.01 | 140.55 | 124.64 | 108.73 |
| 5300 | 270.37 | 415.6 | 368.5 | 321.5 | 147.88 | 131.14 | 114.40 | 145.30 | 128.85 | 112.40 | 142.31 | 126.20 | 110.09 |
| 5400 | 273.69 | 420.7 | 373.0 | 325.4 | 149.70 | 132.75 | 115.81 | 147.08 | 130.43 | 113.78 | 144.06 | 127.75 | 111.44 |
| 5500 | 276.99 | 425.7 | 377.5 | 329.3 | 151.50 | 134.35 | 117.20 | 148.86 | 132.00 | 115.15 | 145.80 | 129.29 | 112.79 |
| 5600 | 280.26 | 430.8 | 382.0 | 333.2 | 153.30 | 135.94 | 118.59 | 150.62 | 133.57 | 116.52 | 147.52 | 130.82 | 114.12 |
| 5700 | 283.52 | 435.8 | 386.4 | 337.1 | 155.08 | 137.52 | 119.97 | 152.37 | 135.12 | 117.87 | 149.24 | 132.34 | 115.45 |
| 5800 | 286.76 | 440.8 | 390.9 | 341.0 | 156.85 | 139.09 | 121.34 | 154.11 | 136.66 | 119.22 | 150.94 | 133.85 | 116.77 |
| 5900 | 289.98 | 445.7 | 395.2 | 344.8 | 158.61 | 140.66 | 122.70 | 155.84 | 138.20 | 120.55 | 152.64 | 135.36 | 118.08 |
| 6000 | 293.18 | 450.6 | 399.6 | 348.6 | 160.36 | 142.21 | 124.05 | 157.56 | 139.72 | 121.88 | 154.32 | 136.85 | 119.38 |

*"Based upon Combs, G.F., 1968. Page 86 in Proceedings Maryland Nutrition Conference for Feed Manufacturers."*

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**Metabolizable energy intake worksheet.**

| Flock Age Days | Week | Daily feed per bird (g) | **x 7 =** | Weekly feed per bird | **x** | ME/g | **=** | ME per week | Cumulative ME |
|---|---|---|---|---|---|---|---|---|---|
| Example: | | 50 | x 7 = | 350 | x | 2.91 | = | 1019 | = 1019 |
| Sum | | | | | | | | | |
| 1 - 7 | 1 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 8 - 14 | 2 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 15 - 21 | 3 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 22 - 28 | 4 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 29 - 35 | 5 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 36 - 42 | 6 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 43 - 49 | 7 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 50 - 56 | 8 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 57 - 63 | 9 | ___ | x 7 = | __ | x | ___ | = | ___ | = ___ |
| 64 - 70 | 10 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 71 - 77 | 11 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 78 - 84 | 12 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 85 - 91 | 13 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 92 - 98 | 14 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 99 - 105 | 15 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 106- 112 | 16 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 113- 119 | 17 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 120- 126 | 18 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 127- 133 | 19 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 134- 140 | 20 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 141- 147 | 21 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 148- 154 | 22 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 155- 161 | 23 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 162- 168 | 24 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 169- 175 | 25 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |

**Crude protein intake worksheet.**

| Flock Age Days | Week | Daily feed per bird (g) | **x 7 =** | Weekly feed per bird | **x** | Decimal %CP | **=** | CP per week | Cumulative protein |
|---|---|---|---|---|---|---|---|---|---|
| Example: | | 50 | x 7 = | 350 | x | .17 | = | 59.5 | = 59.5 |
| Sum | | | | | | | | | |
| 1 - 7 | 1 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 8 - 14 | 2 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 15 - 21 | 3 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 22 - 28 | 4 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 29 - 35 | 5 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 36 - 42 | 6 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 43 - 49 | 7 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 50 - 56 | 8 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 57 - 63 | 9 | ___ | x 7 = | __ | x | ___ | = | ___ | = ___ |
| 64 - 70 | 10 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 71 - 77 | 11 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 78 - 84 | 12 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 85 - 91 | 13 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 92 - 98 | 14 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 99 - 105 | 15 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 106- 112 | 16 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 113- 119 | 17 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 120- 126 | 18 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 127- 133 | 19 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 134- 140 | 20 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 141- 147 | 21 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 148- 154 | 22 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 155- 161 | 23 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 162- 168 | 24 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |
| 169- 175 | 25 | ___ | x 7 = | ___ | x | ___ | = | ___ | = ___ |

# Effects Of Physiological Development On The Management Of Broiler Parent Stock

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To be successful in the business of broiler chick production, it is necessary to appreciate the genetic progress for growth, feed efficiency and meat yield that has been both continuous and dramatic. We are told by Primary Breeders that the growth rate is increasing by 50 grams per year. These economic improvements are of course welcomed by the broiler industry.

However, we do not get something for nothing and the poultry business is no exception. While Primary Breeders strive to balance reproductive performance with the prime broiler objectives, inevitably it becomes a difficult task to achieve both predictable and consistently good chick numbers from parents of high performance broilers.

It is essential that logical rearing management, based on the sequence of physiological development is followed, which would ensure the desired genotype. However, alter the phenotype to resemble a layer — the main parameter being body weight. All Primary Breeders recommend restricted bodyweight profile, which in reality, is approximately 47-50% of a full fed bird.

To devise a rearing programme, which would ensure physiological development, it is useful to divide the growth period from day-old to sexual maturity, into stages.

## 1.1 Day-old To 21 Days:

Chicks are just getting “started”, however, the following development is taking place:

a. Feather cover
  - This could be affected by brooding temperature and stocking density

b. Development of the immune system
  - In the early period, the chick depends on passive immunity derived from the hen, hence, the composition of the maternal diet is critical (Surai, 1999)

c. Development of supply organs, in particular, the cardiovascular system
  - The status of the nutrients, particularly selenium, in the yolk is of importance, marginal deficiency could lead to culls and/or higher rearing mortality (Surai, Sparks, 2000; Lanning et al., 2000)

d. Development of Thermoregulatory Mechanism (TRM)
  - This allows the birds to regulate its body temperature

### *Management Action Required*

a. Sample weigh day-old chicks and calculate average weight. This weight should increase 3 times by 7 days (e.g. day-old weight 40 grams, 7 day weight 120 grams). If the weight does not treble during this 7-day period, then a full audit of brooding management must be done, followed by corrective action.

b. Feed is give ad libitum, however, daily feed intake must be monitored, so that feed can be controlled once the chicks consume 30 grams per bird per day. Thereafter, feed increases are based entirely on bodyweight every week however, two small feed increases in a week are better than one big increase.

c. Weekly sample weighing and monitoring uniformity is necessary to ensure correct decisions on feed increases.

d. Temperature in the brooding area should provide comfort zones, e.g. 31°C under the brooder, 28°C away from the brooder. This will prevent chicks from overheating which would lead to reduced feed intake.

e. Ensure minimum ventilation, i.e. one air exchange every five minutes, Teeter et al., 1998, state 19.6% oxygen is required for adequate development.

f. Feed and water must be fresh and drinker and feeder spacing adequate.

## 1.2 21 Days To 42 Days:

During this period of increasing growth rate, the aforementioned physiological developments continue. This period is characterized by rapid skeletal development; approximately 75% of adult skeleton is achieved by 56 days. It is worth noting that skeletal size dictates the bodyweight at which the bird achieves sexual maturity.

### *Management Action Required*

a. Ensure adequate feed and water space. It is critical that feed is distributed so that all the birds receive the feed at almost the same time so that the flock remains uniform.
b. Getting the birds to the target bodyweight by 28 days of age is an important benchmark, as it indicates that the birds have received adequate amounts of nutrients, in particular amino acids, hence the birds have received a "good start".
c. 35 days of age is a good time to improve uniformity, if required, by grading the flock. It is, however, important to redraw target weights for the heavy and light birds, so that they arrive on standard target weight by 10 weeks of age, i.e. gradually. Remember, uniformity of frame size is essential.

## 1.3 42 Days To 70 Days:

a. Skeletal development continues.
b. Muscle tissue growth is rapid, feed efficiency is at its peak.
c. Tendons and ligaments are strengthening; any decline or stall in weight may result in leg weakness at a later stage.

### *Management Action Required*

Feed increases should be based on bodyweight, preventing stalls or decline. Bodyweight is always increasing.

## 1.4 70 Days To 105 Days:

a. Skeletal development nearing completion.
b. Slow down in bodyweight gain, as the birds undergo feather change.
c. Period is characterized by increasing hormone production associated with preparation towards sexual maturity.

### *Management Action Required*

a. All birds should be on target weight by 10 weeks. However, if any of the group is above or below target, then redraw target weight so that it runs parallel to standard until 15 weeks and thereafter to be on standard bodyweight by 18 to 19 weeks.
b. Avoid stalls or decline in bodyweight.
c. Do not grade.

## 1.5 105 Days To Sexual Maturity (Approximately 161 Days):

a. Acceleration of growth rate from 14 weeks.
b. Rapid production of sex hormones, resulting in rapid ovarian and testicular development. Any decline or stall in bodyweight will interrupt sexual maturity.

### *Management Action Required*

a. Positive weekly feed increases will ensure the rate of bodyweight gain. However, if the bodyweight is under or over the target weight, accept the error and keep the bodyweight parallel to standard bodyweight profile and adjust the light stimulation timing. This is particularly important post 20 weeks of age. One is tempted to get the underweight birds to target by giving more feed. This would result in super ovulation: that is, the ovary will have too many large follicles, a problem known as Erratic Oviposition and Defective Egg Syndrome (EODES) is seen (Robinson, 1995). This condition is accompanied by high incidence of double yolked eggs, which can cause prolapse, laying poor quality or shell-less eggs and egg peritonitis.
b. Light stimulation is best given when 95% of the birds are "ready"; this will be after 20 weeks of age. A model that works well is providing the first light stimulation when 95% of the birds are on or above 2,200 grams bodyweight. The photoperiod at this stage is increased to the maximum and held.

### *Males*

A specific physiological development-taking place in males, apart from all of the above, is worth nothing. Kirby, 1998, reported that the males are developing sertolli cells from an early age to 11 to 12 weeks of age and any stress during this period will therefore reduce sertolli cell count, leading to reduced sperm count later on. Hence, male bodyweight needs to be on or slightly above the standard target at 4, 6, 10 and 12 weeks of age, respectively.

Males may be mixed with females prior to light stimulation at 8-9% mating ratio.

This type of logical rearing programme ensures maximum and repeatable breeder performance, as management actions are based on the sequence of physiological development of the bird.

## Summary

The logical rearing programme outlined above ensures maximum and repeatable broiler breeder performance, as management actions are precisely correlated with, and based on, the sequence of physiological development of the bird.

# Causes And Prevention Of Wet Litter

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Wet litter can be caused by either extrinsic (environmentally related) factors or due to intrinsic flock factors involving excessive excretion of water.

Moisture content of litter exceeding 35% is deleterious and may lead to the following conditions: -

- Dermatitis of the foot pads resulting in pododermatitis which is reflected in poor growth rate in broilers and low fertility in breeder flocks.
- Wet litter contributes to folliculitis (inflammation of the feather follicles) which stimulates gangrenous dermatitis and is responsible for downgrading at processing or rejection by consumers.
- Oocysts of Eimeria spp. require moisture levels in excess of 25% to mature and wet litter is often associated with outbreaks of coccidiosis.
- Necrotic enteritis occurs frequently in houses with areas of wet litter due to the high level of Clostridium perfringens which occurs in the vegetative (infectious) form.
- Damp litter may contribute to proliferation of toxic fungi.
- The bacterial flora of damp litter favors the production of ammonia. If levels exceed 50-ppm, keratitis (erosion of the cornea of the eye) and respiratory stress will occur.

## Causes Of Wet Litter

### *Extrinsic Factors*

- Ingress of rain
  This problem is easy to recognize. Ventilation openings should be closed with shutters or watertight curtains. Houses located in areas subject to seasonal monsoon rains, typhoons or cyclones should be designed to withstand excessive wind and rain. Failure to activate curtains or shutters during rain is a management deficiency.

- Excessive Condensation on the underside of the roof
  Under cold ambient temperature, uninsulated houses develop condensation on the underside of the roof sheeting, which drips onto litter. Appropriate levels of ventilation and the installation of roof insulation are required to correct this problem.

- Leaking Waterers and Piping
  The causes of leakage from suspended bell drinkers and nipple systems should be investigated, followed by appropriate corrective action. This may involve installation of a pressure regulator or filters to prevent particulate matter which clogs valves from entering water lines. Non-ballasted drinkers, especially when suspended at an incorrect height, will spill water causing wet patches beneath drinker lines. Flooding will occur if rodents gnaw plastic water lines.

### *Intrinsic Factors*

Excretion of water may occur in the form of urine (diuresis) or from the digestive tract (diarrhea). It is important to establish whether excessive release of fluid from the cloaca (wet droppings) is from the urinary or the digestive tract.

- **Diarrhea**
  Infection of the intestinal tract will result in diarrhea. The causes include:
  - Coccidiosis. This infection can be diagnosed by examination of intestines of sacrificed birds showing ruffled plumage and palor. Microscopic examination of mucosal scrapings confirms the diagnosis. Administration of appropriate therapy (sulpha drugs or amprolium) will restore normal function.
  - Bacterial Infections will result in enteritis. Microscopic and microbiological examination of intestines from affected sacrificed birds are required to establish the diagnosis. Appropriate

antibiotics (tetracycline, neomycin, zinc bacitracin or ampicillin should be administered in accordance with statutory regulations, manufacturer's recommendations and the principles of prudent therapy.

- Viral infections including reovirus and other enteric viral agents can result in diarrhea especially in young flocks. This may last for a few days to a week. Diagnosis is based on electron microscopy of mucosal scrapings and feces, histological examination of intestinal tissue and attempts at viral isolation. All these procedures require a specialized laboratory. There are no specific treatments for viral infections other than supportive therapy comprising electrolyte supplements and raising the brooding temperature.
- Malabsorption of complex carbohydrates. Non-starch polysaccharides contained in wheat, barley, and some indigenous materials such as cassava cannot be completely digested in the anterior intestinal tract, resulting in digestive malfunction, bacterial degradation and diarrhea. Substitution of maize for alternative cereals and using high quality soybean meal in place of potentially toxic vegetable proteins should be considered. The digestibility of wheat, barley and unconventional carbohydrate sources can be improved by supplementing diets with specific enzyme combinations which are commercially available.
- Mycotoxins including aflatoxin and fusariotoxins are responsible for diarrhea. Analysis of feed will confirm the presence of these toxins. Appropriate corrective action involves substitution of non-contaminated ingredients or supplementing diets with an effective mycotoxin binder.
- Feeds containing rancid fat due to prolonged storage at high temperature will result in diarrhea. Incorporation of non-stabilized fat, byproduct meal or rice bran in tropical countries is a frequent cause of wet droppings, pasty vents and other deleterious effects including encephalomalacia, immuno suppression and low growth rate.

- ***Diuresis***

  Birds will excrete excessive quantities of water at high ambient temperature. This is a normal result of increased water intake. High water consumption is a physiological response which enables the bird to dissipate body heat by evaporative cooling through the respiratory tract. Ingestion of cold water serves as a heat sink in the digestive tract, lowering core body temperature.

  - Excessive salt or sodium or chloride in the diet will result in excessive water intake and diuresis. Improper levels of salt may be the result of incorrect formulation, defective mixing or accidental contamination of diets. High levels of salt may occur inadvertently through incorporating batches of fishmeal or carcass meal with a high sodium chloride content. Occurrence of diuresis or wet droppings following a change in diet or purchase of feed from a new source should be investigated, with appropriate analyses. Magnesium contamination of limestone in layer and breeder diets may also result in diuresis.
  - Chemical and mineral impurities in water including sodium and magnesium may result in diuresis. Appropriate analysis of water will confirm the cause of diuresis which is usually a chronic problem in the flock.
  - Mycotoxins including ochratoxins damage the kidney and will result in excessive excretion of water. The condition can be diagnosed by demonstrating the specific mycotoxin in feed associated with microscopic examination of kidneys of affected birds.
  - Flocks infected with a number of nephropathogenic (affinity for the kidney) viruses may show diuresis during the acute and recovery phases of infection. Diuresis is observed with acute infectious bursal disease, avian nephrosis virus and nephropathogenic strains of infectious bronchitis virus.
  - Replacement broiler breeder pullets subjected to skip-a-day feeding will show diuresis as a result of excessive water intake on non-feed days. Mature hens on post-peak restriction often demonstrate excessive water intake with resultant wet droppings. It is often necessary to implement a water restriction program, subject to the breeder's recommendations regarding feed and water intake. It is inadvisable to implement a water restriction program if the flock is subjected to an ambient temperature above 30°C.

# Nutrition Of Intensively Raised Ducks

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Ducks are raised for both meat and eggs throughout Asia, and are an important component of animal agriculture in Indonesia, Philippines, Thailand, Malaysia, Vietnam, Taiwan and China.

Many systems are used for duck production in Asia, and in some of them nutrition inputs are provided through scavenging, a combination of scavenging and/or use of ingredients such as rice bran, snails etc. However, large numbers of ducks are fed on balanced, mixed diets, often in pelleted form. Varieties of ducks used vary greatly from country to country. All of this makes it difficult to define nutrient requirements. In this article an attempt is made to provide information on the feeding of ducks for both meat and eggs. The information is derived from experience, and from a number of literature sources. For meat ducks, most information relates to the Pekin type of meat duck. For laying ducks, the information is believed suitable for small bodyweight laying ducks such as the Indian Runner type.

## Nutrient Requirements

**Meat/growing ducks.** Information on nutrient requirements is provided in Table 1. Meat ducks of the Pekin type are commonly fed with a 2 stage program, incorporating a starter to 2 weeks of age, then a grower diet to market. Market weight of around 3 kg liveweight is common, achieved at 42-45 days of age. A program which is nutritionally more correct would be a 3 stage program using a starter diet to 2 weeks, a grower diet 2-4 weeks followed by a finisher diet to market.

**Table 1. Nutrient requirements for meat ducks**

| | Starter | Grower | Finisher |
|---|---|---|---|
| ME, Kcal/kg | 2,850-2,950 | 2,900-3,000 | 2,950-3,150 |
| Digestible Lysine, % | 0.950 | 0.720 | 0.620 |
| Digestible Methionine, % | 0.342 | 0.288 | 0.240 |
| Digestible M+C, % | 0.665 | 0.540 | 0.450 |
| Digestible Tryptophan, % | 0.171 | 0.144 | 0.120 |
| Digestible Threonine, % | 0.618 | 0.504 | 0.420 |
| Digestible Arginine, % | 0.998 | 0.778 | 0.648 |
| Digestible Isoleucine, % | 0.675 | 0.497 | 0.414 |
| Digestible Valine, % | 0.732 | 0.576 | 0.480 |
| Calcium, % | 1.00 | 0.90 | 0.85 |
| Avail. Phosphorus, % | 0.40 | 0.36 | 0.34 |
| Sodium, % | 0.20 | 0.16 | 0.16 |
| Linoleic acid, % | 1.00 | 1.00 | 1.00 |
| Choline, mg/kg | 1,750 | 1,500 | 1,250 |

- *starter 0-2 weeks, grower 2-4 weeks, finisher 4 weeks plus*
- *feed pellets of good quality*

Energy levels both higher and lower than those indicated in Table 1 may be fed. Lower energy levels tend to be used when low energy/high fibre by-products such as rice bran, and wheat bran are readily available, and are desired to be used at high levels. Higher energy levels, achieved through fat addition, will tend to increase growth, but may lead to fatter carcasses.

Minimum protein levels are not indicated, and are not necessary if formulation is on the basis of these 8 digestible amino acids. However in practice, 20-21% protein will be seen in starter diets, 16-18% protein in grower diets, and 14-16% protein in finisher diets.

Amino acid requirements are expressed in digestible terms, which is preferred. If formulating with total amino acids, calculate total lysine requirement by dividing digestible lysine requirement by 0.85, then calculate other amino acids in proportion to lysine.

Fat levels in the carcass may be influenced by energy, or more correctly energy/protein ratio of the feed. High ratios tend to increase fat levels, and vice versa. This is of course also influenced by the genotype of the ducks. For the Chinese type of roast duck, a strong layer of fat beneath the skin is desired and a higher energy/protein ratio is used to achieve this.

**Laying ducks.** Information on nutrient requirements for laying ducks is provided in Table 2. One set of nutrient specs is given, although a second stage diet with somewhat lower amino acid specs may be fed from around 20 week into the laying period.

Energy levels lower than those indicated in Table 1 may be fed. Lower energy levels tend to be used when low energy/high fibre by-products such as rice bran, and wheat bran are readily available, and are desired to be used at high levels. Laying ducks will perform well on lower energy diets.

Minimum protein levels are not indicated, and are not necessary if formulation is on the basis of these 8 digestible amino acids. However in practice, 17-19% protein will be seen in laying duck diets.

Amino acid requirements are expressed in digestible terms, which is preferred. If formulating with total amino acids, calculate total lysine requirement by dividing digestible lysine requirement by 0.85, then calculate other amino acids in proportion to lysine.

**Table 2. Nutrient requirements of laying ducks**

| Item | Value |
|---|---|
| ME, Kcal/kg | 2,850 |
| Digestible Lysine, % | 0.80 |
| Digestible Methionine, % | 0.36 |
| Digestible M+C, % | 0.64 |
| Digestible Tryptophan, % | 0.16 |
| Digestible Threonine, % | 0.58 |
| Digestible Arginine, % | 0.96 |
| Digestible Isoleucine, % | 0.616 |
| Digestible Valine, % | 0.72 |
| Calcium, % | 3.5 |
| Available Phosphorus, % | 0.38 |
| Sodium, % | 0.24 |
| Linoleic acid, % | 1.0 |
| Choline, mg/kg | 1,250 |

- *Assumed feed intake minimum of 150 grams*
- *Ideally feed pellets of good quality*

## Feeding Method

Growth rates and feed efficiency are improved when ducks are fed pelleted or crumbled diets. Pelleted diets are commonly fed to ducks of all classes. Mash feed can be used but are rather inefficient, as mash feed tends to form a sticky paste when mixed with saliva, which cakes and accumulates on the outer ridges of the mouth. Ducks then make frequent trips to water to wash their bills, causing feed wastage. One solution is to feed wet mash. Dry mash should be mixed with water just before feeding, and enough water added to form a thick "gruel" without making it too watery. Mixing and delivery of wet feed could be automated, as is common in feeding pigs.

In the case of pelleted diets, good pellet quality, with a minimum of fines (less than 5%) should be fed. Pellet diameter of 2-3 mm for young ducks is suitable, while up to 4 mm can be used for ducks over 2 weeks of age, and for laying and breeding ducks.

## Ingredient Use

There is considerable information, often anecdotal, on the suitability of various ingredients for ducks. In practice many duck diets closely resemble diets for chickens, in being largely corn-soybean meal type. However there is some information on individual ingredient use which should be considered:

**Corn.** Is a major grain for feeding ducks in many Asian countries? For example duck diets used for the large duck industry in Taiwan are predominantly corn-soybean meal. Corn may be contaminated with high levels of aflatoxins, depending on conditions around harvest and during storage, and this should be checked by assay.

**Cassava.** This high starch root product is used in duck diets in countries such as Thailand. The author has seen pelleted diets devoid of corn or other grains and therefore with levels of cassava over 60% used for Pekin-type meat ducks in Thailand recently, apparently with good results. Contrary to some opinions, cassava is not associated with aflatoxin.

**Wheat.** When available and economic, wheat is an excellent grain for ducks. It gives good pellet quality due to the gluten protein, and is devoid of aflatoxins. Wheat can be used as the sole grain. A xylanase enzyme should be used when using wheat.

**Wheat/rice by-products.** Ingredients such as fullfat rice bran, extracted rice bran, wheat bran, and wheat pollard appear to be well utilised by ducks. There are indications that they are better utilised than by chickens of similar age. Research work from Indonesia in the late 1970's showed consistently that rice bran could be used up to quite high levels for growing ducks without growth depression, while similar levels reduced growth in broiler chickens.

Martin and Farrell (1995b) measured a much high energy level for rice bran in young ducks than in chickens (3,728 vs. 2,510 Kcal ME/kg DM for duck and chickens 3-7 days of age).

In an enzyme trial in the Philippines, shown in Table 4, a diet with 50% wheat pollard gave equal egg production, equal egg size, similar feed intake, and similar bodyweight change to a wheat-based diet, despite having a book value of 200 Kcal/kg lower energy. This suggests that the 2,000 Kcal ME/kg assigned to the wheat pollard was an underestimate of its actual energy value.

**Animal protein meals.** Fishmeal is a common component of ducks diets. Other animal protein meals likely to be used would be mbm, blood meal, and poultry by-product meal. There is some suggestion that ducks perform better with such animal protein meal (Martin and Farrell, 1995a). However it seems unlikely that ducks should be any different in this regards to broiler and layer chickens, where correctly formulated diets do not benefit from the inclusion of animal protein meals (Srinongkote et al., 2001).

**Copra meal/cottonseed meal, groundnut meal.** These protein meals tend to be avoided for use in duck diets, due to their potentially high levels of aflatoxin. Otherwise they are suitable ingredients, but testing for aflatoxins is recommended before use.

**Broken rice.** This is an excellent grain for ducks, having a high energy value, above that of corn and wheat, and being free of aflatoxins.

## Feed Additives

Several additives which may be useful in duck diets are discussed in this section:

1. **Phytase.** Microbial phytase releases phosphorus from the phytate found in grains, grain by-products, and vegetable protein meals. Digestibility of amino acids and of energy are increased as a result. Little work has been done with phytase for ducks. However a trial from China with laying ducks suggests that phytase is effective in this species, and should be economic to use (Heindl, 2000).

   Chinese Shaoxin laying ducks were used. Dietary treatments included a positive control (practical commercial diet) and a negative control with reduced phosphorus. The phosphorus reduced diet was supplemented with 300, 400 or 500 FTU phytase/kg diet. The diets consisted mainly of corn, soybean meal, wheat bran and fishmeal. Results are shown in Table 3. Phytase improved feed efficiency and gave large increases in egg production.

   The published work of Farrell and Martin (1993) also indicate that phytase is effective in meat-type ducks.

**Table 3. Effect of phytase* on performance of laying ducks in China**

| Treatment | Positive Control | Negative Control | | | | SEM | P |
|---|---|---|---|---|---|---|---|
| Phytase | - | - | 300 FTU | 400 FTU | 500 FTU | | |
| Feed Intake g/d | 176.6 | 173.6 | 169.1 | 171.4 | 172.4 | 2.999 | 0.523 |
| Egg Weight g | 62.07 | 62.50 | 61.82 | 61.95 | 61.22 | 0.268 | 0.073 |
| Egg Production % | 78.6c | $74.5^{d}$ | $80.7^{bc}$ | $82.8^{b}$ | $89.5^{a}$ | 1.156 | 0.0001 |
| FCR kg/kg | $3.49^{a}$b | $3.58^{a}$ | $3.39^{b}$ | $3.25^{bc}$ | $3.16^{c}$ | 0.085 | 0.034 |

*$^{abcd}$ $P<0.05$. * Natuphos, BASF*

2. **Xylanase.** Fibre digesting enzymes, based on xylanase or combinations of xylanase with other cellulases, protease and amylase appear to be effective in improving digestibility of diets based on either wheat or corn, and should be considered for use.

   In a trial conducted at the Institute of Animal Science, University of the Philippines, Los Banos, a *Trichoderma* xylanase enzyme improved egg production, daily egg mass, feed conversion, and weight gain in ducks fed diets based on either wheat or wheat pollard (Creswell, 1995).

   In a trial conducted at Purdue University, USA, a *Trichoderma* xylanase enzyme was tested in wheat-based diets for meat ducks (Table 5). Enzyme addition improved the FCR of the ducks by 14 points (control group FCR 2.61 vs enzyme group FCR 2.47), and increased weight gain by 332g (2416g vs. 2748g).

**Table 4. Effects of a xylanase enzyme* on performance of laying ducks (20 weeks production)**

| | Wheat | Wheat + enzyme | Wheat pollard | Wheat pollard + enzyme | P value (enzyme effect) |
|---|---|---|---|---|---|
| Egg production, % | 53.2$^{b}$ | 60.5$^{a}$ | 58.5$^{a}$ | 58.6$^{a}$ | 0.04 |
| Egg weight, g | 71.2 | 69.6 | 69.8 | 71.0 | 0.90 |
| Feed Intake, g/d | 133 | 128 | 129 | 131 | 0.65 |
| Egg Mass, g/d | 37.8$^{b}$ | 42.1$^{a}$ | 40.8$^{a}$ | 41.6$^{a}$ | 0.04 |
| Feed Conversion, g/g | 3.52$^{b}$ | 3.04$^{a}$ | 3.17$^{ab}$ | 3.14$^{ab}$ | 0.05 |
| Weight Gain, g/bird | 230$^{b}$ | 300$^{a}$ | 240$^{b}$ | 330$^{a}$ | 0.04 |
| Shell % | 9.65 | 9.99 | 9.75 | 9.93 | 0.15 |
| Shell Thickness, um | 438 | 440 | 431 | 437 | 0.25 |
| Yolk Colour, Roche scale | 10.3 | 9.7 | 10.4 | 11.4 | 0.21 |
| Mortality, % | 5 | 2.5 | 0 | 2.5 | - |

*ab P<0.05 * Avizyme 1300, Finnfeeds*

In a trial conducted at the Roslin Research Institute, UK, the effect of adding a Bacillus based protease, a Bacillus based amylase and Trichoderma based xylanase enzyme complex on the performance of ducks fed corn-soybean meal based diets up to 42 days of age was measured. Both diets were fed as pellets. Results are shown in table 6.

Enzyme addition resulted in a 5-point improvement in FCR (p<0.01). The enzyme fed ducks were also heavier and were of a more uniform bodyweight.

**Table 5. The effect of a xylanase* on duck performance (7-46 days)**

| | Weight gain, g | Feed intake, g | FCR, g/g |
|---|---|---|---|
| Control | 2416$^{b}$ | 6292$^{b}$ | 2.61$^{a}$ |
| + Enzyme | 2748$^{a}$ | 6794$^{a}$ | 2.47$^{b}$ |
| P value | 0.0001 | 0.001 | 0.011 |

*$^{ab}$ values with no common superscript differ significantly. * Avizyme 1310, Finnfeeds*

**Table 6. The effect of a protease, amylase and xylanase enzyme complex[1] on duck performance (1-42 days).**

| | Weight gain, g | Feed intake, g | FCR, g/g | Uniformity of bodyweight[2], % |
|---|---|---|---|---|
| Control | 3097 | 6362 | 2.05$^{a}$ | 91.42 |
| + Enzyme | 3152 | 6308 | 2.00$^{b}$ | 93.00 |

*$^{ab}$ values with no common superscript differ significantly at P<0.01*

*[1] Avizyme 1500, Finnfeeds*

*[2] Percentage of ducks of average bodyweight 15%*

3. **Antibiotics.** Low level antibiotics as growth promoters are commonly used in diets for growing ducks. Responses appear to be similar to that in chickens. Given the low costs of these, they are generally believed to be economic. Products used are virginiamycin, zinc bacitracin etc. Antibiotic use in layer ducks is probably not necessary, or advisable.

4. **Beta agonists.** There are several literature reports indicating that beta agonists may be effective in meat-type ducks. Cimaterol was tested at several levels in Pekin ducklings (Dean and Dalrymple, 1988). At 0.25 ppm inclusion in feeds, Cimaterol increased breast muscle weight 21%, increased thigh + drumstick muscle weight 13%, decreased weight of the skin-fat layer 9%, and improved feed conversion 2.5% with no effect on bodyweight gain. Farrell (1991) showed reduced carcass fat and abdominal fat pad with 4 ppm Cimaterol. There is widespread use of these products in some Asian countries, for example Malaysia.

   Ractopamine is the only beta agonist developed specifically for animal feed use, which has been found to be safe and has been approved for use in pigs, by the FDA of the U.S.A. and in a number of other countries, including Philippines and South Korea. To the author's knowledge, this product has not been tested with ducks.

## Aflatoxins

The high susceptibility of ducks to aflatoxins is well known. Among poultry, ducks are the most susceptible type. It is suggested that aflatoxin levels as low as 25 ppb in feed will cause increased mortality and liver lesions in laying ducks. Thus all ingredients and the final feed should be screened for aflatoxin levels on a continuous basis. An effective toxin binder might be useful where there is a risk of aflatoxins.

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# Nutritional Requirements Of Modern Laying Hens

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The ability of nutritionists to formulate feed to provide nutrient levels for optimum economic layer performance is dependent upon understanding the microenvironment in which layers are reared, and upon adjusting feed formulations for those changes in feed intake caused by the environment. The environmental temperature has a tremendous influence on feed consumption, because the layers try to maintain a homeostatic body temperature by adjusting the intake of nutrients to the amount of heat the laying hen dissipates. The dietary requirements for ME and amino acids for layers should be based on specific environmental conditions, maintenance needs and product output. The maintenance energy requirement for layers is very dependent on environmental temperature and body size and has a tremendous effect on total daily feed intake.

It has been said that the commercial egg-type laying hen “lays eggs with its beak”. In other words, it is essential that the layer consume adequate nutrients and energy each day if she is expected to perform at her full genetic potential. Many times the hen’s performance is limited by inadequate nutrition. The hens will use the nutrients and energy for maintenance, general activity, egg production, size and growth. The size of the hen will influence the amount of feed she consumes. Layers of a light strain will normally consume less feed than a heavier strain. However, both light and heavier strains are very capable of high production. Environmental temperature is known to influence feed intake. Feeding adjustments can help to overcome some of the production drops, which occur in layer flocks due to increased environmental temperature. Feed adjustments are not the only solution, and some management practices will also contribute to alleviate the problem.

Warmer environmental temperatures that lower feed intake and energy requirements of layers may be economically beneficial if the temperatures registered at the farm are not extreme and the nutrient concentration of the feed is increased to compensate the decreased feed intake.

In recent years, the Management Guides for the Commercial layer edited by the Breeder Companies, have recommended substantial dietary increments in protein, amino acids, calcium, phosphorus and energy to allow maximum performance. Higher levels of protein and amino acids have also been encouraged in modern feed formulas because of their stimulus to egg size. The daily amino acid requirements for layers are primarily affected by egg mass output with a small percentage of daily needs used for maintenance. The increase in dietary protein levels in feed formulas is usually from feedstuffs with a lower metabolizable energy, thus nutritionists have been forced to add fat to keep dietary energy levels equal to the past. Being the quality of the energy utilized as important as the quality of the protein itself, the use of FFSBM represents a unique opportunity to supply both nutrients.

The continuing trend of Commercial Breeders to produce genetic stock with combined lower expected feed intake and genetic potential for increased egg mass production will require nutritionists to truly understand the importance of specific nutrients and also know the amount of nutrients needed for specific functions. The present laying hen utilized by the industry has been genetically selected to initiate lay at an earlier age, produce more egg mass, and consume less feed than the layers of the past.

## Temperature And Dietary Energy Levels On Layer Performance

As mentioned before, temperature has a direct influence on feed consumption and total energy intake. Egg mass is consequently affected by both very low and high temperatures. In general terms, body weight is increased by feeding high energy diets, and body weight gain is decreased as temperature increases.

Whenever layers are housed in hot climates, feed intake is lower than when they are housed in cooler climates. The decrease in feed intake will, in many instances, cause problems in the performance of the flock. Feed consumption is lower due to the reduced daily energy that the hens require for maintenance. In other words, the higher environmental temperature reduces the daily energy need of the hen for maintaining her body temperature due to her body temperature being closer to environmental temperature. Less heat is being dissipated from her body to the environment due to the narrow temperature gradient between her body temperature and the environmental temperature. Body weight gain is not as great in hot weather, total egg production and egg size are depressed and egg shell quality problems are usually present, especially after 40 weeks of age. Therefore, the major concern in hot weather is the decreased nutrient and energy intake of the flock to sustain egg production, egg weight and shell quality.

Two main options are available to increase energy consumption in hot weather. Feed intake can be stimulated and/or more energy can be added to the diet by increasing the caloric density of the feed. Several methods exist in order to achieve the first option, like flushing water lines several times a day, increasing the number of feedings per day from 3 to 4, to 6 or 7 times each day.

The second option is to increase the energy content of the diet. To accomplish this, the use of supplemental fat needs to be considered. Fat will not only add more energy to the diet, but will provide an “extra caloric” effect in hot weather. Dietary fat will improve the palatability of the feed. The laying hen and other poultry will usually adjust their feed intake according to the energy content of the diet. When the energy content is high, the bird consumes less feed and vice versa. However, this adjustment mechanism seems less perfect at higher environmental temperatures. Therefore, the bird may slightly over consume on calories in hot weather for a short period of time when higher dietary energy levels are used. Thus would be especially true when supplemental fat is added to the diet. Again, fullfat soybeans are very useful in hot weather.

In an experiment run by Zollitsch et al., in 1996, Dekalb layers housed at 30.5°C had the advantage of a lower maintenance requirement, because of the warm temperature, and although the hens consumed significantly less feed from this environment, the hens were able to consume enough feed to produce near maximum output of egg mass. In this same feeding trial, the overall optimum environmental temperature and dietary energy level for maximum feed efficiency and egg mass production was set at 30.5°C and 2976 Kcal ME/kg.

According to the Hy-line Brown Layer Management Guide the energy requirement for a layer under a moderate environmental temperature can be calculated using the following equation:

Kcal/bird/day = W (140 – 2T) + 2E + 5 ^^ W

Where,
W = current body weight in kilograms
T = Average environmental temperature in Celsius degrees.
E = Daily egg mass in gr/bird/day

$$\frac{\text{(\% production x egg weight in gr)}}{100}$$

^^ W = Increment in body weight in gr/bird/day

The daily energy consumption can de determined as follows:

Kcal/kg of feed x g/bird/day by 1000 = Kcal/bird/day

In the same way, the amount of calories in feed can be calculated to reach a daily consumption determined following the next equation:

$$\text{Kcal/kg of feed} = \frac{\text{Kcal/bird/day (desired) x 1000}}{\text{g/bird/day (actual)}}$$

They recommend relatively high energy levels when the total consumption of energy is a restrictive factor. This includes critical periods between housing and maximum production. Lots with an energy consumption below 285 Kcal/bird/day during the laying period tend to suffer egg production reductions and the egg size is also reduced. Again, heat stress will also result in a low feed and energy consumption. Increasing nutrient density, including energy (a moderate amount of fat) will contribute to maintain production yield and egg size when the environmental temperatures are high.

Again, fat is a concentrated energy source that can be used to increase the energy content in feed. Vegetable fat has the additional advantage of producing relatively low body heat increments, which is useful during periods of heat stress. Soybean oil has a high content of linoleic acid, which contributes to increase egg size.

The following chart is a guide to add fat to the feed according to different ages and environmental temperatures. Upon the addition of fat to the ration, the nutritionist should be careful of adding other nutrients in proportion to the energy.

### Added Fat (%)

| Daily Maximum | Growing period | Housing until max. prod. | After max. prod |
|---|---|---|---|
| Above 35°C | 3% | 3% | 2% |
| 30 to 35°C | 2% | 2% | 1% |
| Below 30°C | 0 | 1% | 0 |

If a country does not pay a premium for egg size, then the most efficient system would be to provide layers with a warmer environment to lower maintenance requirements and keep nutrient intake adequate for maximum egg output without feeding additional nutrients for extra egg size.

### The Effect Of Adding Dietary Fat To Increase Egg Mass Response With Total Sulfur Amino Acid Levels

In general terms, it has been observed that the addition of sulfur amino acids (methionine from 650 – 750 mg) has no effect on egg production, egg mass or egg weight, unless accompanied with the addition of fat ranging from 2 to 4%. The addition of higher levels of TSAA seems to be related to an increment in the weight of the yolks, while the increment in the concentration of ME seems to be related to an increment in the number of eggs produced. However, ME is also related to the production of a larger egg mass as we can see when a higher level of TSAA is utilized. Werner et al., report that the percentage of egg yolk from hens fed diets containing 2900 and 3050 kcal ME/kg was higher than the percentage of yolk in those eggs from hens fed from 2450 to 2600 kcal ME/kg .

When layers are severely energy deficient, the addition of energy will first show a large increase in egg numbers (egg weight may actually decrease), and then as the energy requirements for egg numbers are obtained, the hen partitions more to egg weight.

### Feeding Optimum Levels Of Protein And Essential Amino Acids For Layers

The development of an ideal protein and amino acid profile for layers is needed to minimize layer nitrogen waste, potentially improve performance in hot temperatures with less heat increment, and increase the economic return of dietary protein and amino acids by improving the amino acid efficiency of utilization. A key problem associated with the validity of an "ideal protein concept" for layers is that past research has indicated layers need protein per se (Penz and Jensen, 1990) for producing larger egg albumen weights and total egg weights. At the same time covering a minimum level of total lysine and digestible lysine in the ration is directly related to an optimum feed conversion and thus optimum egg mass production by the layers (Rostagno, 2002).

Summers et al., (1990) reported that layers fed a 10% protein diet supplemented with methionine, lysine, tryptophan, and arginine produced 11% less egg mass compared to layers fed 17% protein diets. A few years later Harms and Ivey (1993) suggested the order of limiting amino acids for layers fed corn-soybean diets is methionine, lysine, tryptophan, arginine, and valine.

The egg composition and performance of layers fed corn – soy – meat and bone 14% CP diets with added methionine, lysine, isoleucine, and valine is equal to layers fed 18% CP control diets. The research has shown that the different commercial layer strains fed 14% protein diets with added amino acids to provide an ideal protein, perform equal to layers fed higher protein diets. Nitrogen loss in excreta is about 15 percent less for layers fed 14% protein diets supplemented with amino acids compared to layers fed 18% protein diets. The order of limiting amino acids in a 14% CP corn-soy-meat and bone diet is methionine, TSAA, isoleucine, valine, lysine, arginine, threonine, and tryptophan. It takes approximately a 16% CP diet consisting of corn-soy-meat and bone meal to provide the correct levels of digestible isoleucine, and valine for a hen consuming 100 grams of feed daily.

Presently, it is not economical to add synthetic isoleucine or valine to poultry diets. (Coon, 2001). Most layer management guides suggest a 16% CP diet from 50% laying rate to reach maximum production (32 weeks) and from 32 to 44 weeks of age, except for Hy-line Brown and Lohmann who recommend an average of 18 % CP. However, for the ideal protein concept to be adequately applied, the level of lysine is to be taken as a sound reference to estimate the requirements for the rest of the essential amino acids. In addition to this feed consumption, as determined by strain and climatic conditions (mainly temperature and humidity), will influence the total energy consumption, and based on this, the final protein, lysine and the other amino acid concentrations are to be set for a maximum layer performance (Rostagno, 2002). Feeding imbalanced diets with regard to protein and amino acids will result in increased amino acid catabolism and thus in increased heat production.

## Calcium Requirements In Laying Hens

The last NRC publication (NRC, 9th Edition, 1994) suggested the calcium requirement was only 3.25% for 100 gram intake, however, the committee stated that the requirement might need to be higher for maximum egg shell thickness. The continuing recommended increase in dietary calcium for layers is probably justified because of an overall increased shell mass production during the laying cycle.

The different forms of dietary calcium and the large range in particle size utilized in previous layer studies may have been partially responsible for the variations in response to calcium. Coon determined in a recent study that the optimum solubility range for limestone is between 11 and 14%. This solubility value can be obtained by mixing the right portion of limestones of various sizes.

Since bone calcium will be mobilized to support dietary calcium levels during egg shell formation, nutritionists need to feed a level of dietary calcium that will not deplete all bone reserves of calcium during the complete laying cycle. Research indicates that feeding optimum calcium levels and the correct limestone solubility to young layers and then continuing with this system during the entire laying period will help support stronger bones and egg shells at the end of the entire laying cycle.

To maximize egg shell quality and maintain strong bones, older layers at the end of a laying cycle may need a lower soluble limestone (8 to 10%) and a higher calcium intake (5 gr. for eggs shells and 6 gr. for bones).

## Vitamins And Minerals In Feed Under Heat Stress Conditions

In order to maintain the consumption of adequate daily quantities of minerals and vitamins when feed intake decreases, their percentage in the diet should be increased. Sometimes adding large particle limestone and oyster shell with the proper solubility to the top of the feed is beneficial in maintaining calcium consumption in hot weather. Research has shown that hot weather does not have an effect on calcium source solubility in the hen’s digestive tract. The calcium sources with lower solubility in the digestive tract will be retained longer in the tract and the calcium will be available during the night when the egg shell is being formed. This is why midnight feeding and feeding calcium sources of lower solubility are associated with improved egg shell quality.

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# Optimum Production And Nutrition Of Layers

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The potential of the modern layer strains for egg production is very high, and continues to increase with every new generation, due to the selection programs of the major breeders. It is important to understand what this potential is, and to strive to achieve it.

This paper discusses the potential of current layer strains, with examples given of actual flock performance, the nutrient requirements needed to achieve that potential, and factors to work on to achieve this potential under Asian conditions.

## Production Standards

The place to look for standards of production are the management manuals provided by the breeding companies. Here we will find numbers, which represent the potential of the layer under conditions of good management, good quality pullets, good quality feed, absence of disease and a suitable environment. These standards are high, but are achievable. Since all countries in Southeast Asia are using the international strains, these are the standards we must compare against. The standards are not very different between strains, with the exception that white egg strains, as used in the Philippines for example, are smaller in bodysize and feed consumption. However egg production numbers are not very different between all strains. Table 1 gives the standards for the Hy-Line Brown strain. These figures would largely apply to all the major brown egg laying strains.

**Table 1. Production standards for the Hy-Line Brown layer strain**[1]

| Age, weeks | Hen Day Production,% | Cumulative. Mortality, % | Hen Housed Eggs Cumulative | Body weight, kg | Egg weight, grams | CumulativeEgg Mass, kg |
|---|---|---|---|---|---|---|
| 18 | 1 | 0.1 | - | 1.55 | - | - |
| 19 | 8 | 0.1 | 0.6 | 1.61 | 46.6 | 0.0 |
| 20 | 25 | 0.2 | 2.3 | 1.66 | 47.6 | 0.1 |
| 21 | 51 | 0.2 | 5.9 | 1.71 | 49.3 | 0.3 |
| 22 | 76 | 0.3 | 11.2 | 1.75 | 51.5 | 0.6 |
| 23 | 89 | 0.3 | 17.4 | 1.79 | 54.0 | 0.9 |
| 24 | 93 | 0.4 | 23.9 | 1.83 | 56.3 | 1.3 |
| 25 | 94 | 0.4 | 30.4 | 1.86 | 58.1 | 1.6 |
| 26 | 94 | 0.5 | 37.0 | 1.90 | 59.7 | 2.0 |
| 27 | 95 | 0.5 | 43.6 | 1.95 | 60.4 | 2.4 |
| 28 | 95 | 0.6 | 50.2 | 1.96 | 61.1 | 2.8 |
| 29 | 94 | 0.6 | 56.7 | 1.99 | 61.4 | 3.2 |
| 30 | 94 | 0.7 | 63.3 | 2.01 | 61.7 | 3.7 |
| 31 | 94 | 0.7 | 69.8 | 2.04 | 62.0 | 4.1 |
| 32 | 94 | 0.8 | 76.4 | 2.06 | 62.3 | 4.5 |
| 33 | 94 | 08 | 82.9 | 2.08 | 62.6 | 4.9 |
| 34 | 94 | 0.9 | 89.4 | 2.10 | 62.9 | 5.3 |
| 35 | 94 | 0.9 | 95.9 | 2.11 | 63.2 | 5.7 |
| 36 | 93 | 1.0 | 102.4 | 2.13 | 63.5 | 6.1 |
| 37 | 93 | 1.0 | 108.8 | 2.15 | 63.7 | 6.5 |
| 38 | 93 | 1.1 | 115.3 | 2.16 | 63.9 | 7.0 |
| 39 | 93 | 1.1 | 121.7 | 2.17 | 64.1 | 7.4 |
| 40 | 92 | 1.2 | 128.1 | 2.18 | 64.3 | 7.8 |
| 41 | 92 | 1.2 | 134.4 | 2.19 | 64.4 | 8.2 |
| 42 | 91 | 1.3 | 140.7 | 2.20 | 64.5 | 8.6 |
| 43 | 91 | 1.4 | 147.0 | 2.21 | 64.6 | 9.0 |
| 44 | 90 | 1.4 | 153.2 | 2.22 | 64.7 | 9.4 |
| 45 | 90 | 1.5 | 159.4 | 2.22 | 64.8 | 9.8 |
| 46 | 89 | 1.5 | 165.5 | 2.23 | 64.9 | 10.2 |
| 47 | 89 | 1.6 | 171.7 | 2.23 | 65.0 | 10.7 |

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[1] *From the Hy-Line Brown Commercial Management Guide 2000-2001*

**Table 1. Production standards for the Hy-Line Brown layer strain**[1]

| Age, weeks | Hen Day Production,% | Cumulative. Mortality, % | Hen Housed Eggs Cumulative | Body weight, kg | Egg weight, grams | CumulativeEgg Mass, kg |
|---|---|---|---|---|---|---|
| 48 | 88 | 1.7 | 177.7 | 2.24 | 65.1 | 11.1 |
| 49 | 87 | 1.7 | 183.7 | 2.24 | 65.2 | 11.5 |
| 50 | 87 | 1.8 | 189.7 | 2.24 | 65.3 | 11.8 |
| 51 | 87 | 1.8 | 195.7 | 2.24 | 65.4 | 12.2 |
| 52 | 86 | 1.9 | 201.6 | 2.24 | 65.5 | 12.6 |
| 53 | 86 | 2.0 | 207.5 | 2.24 | 65.6 | 13.0 |
| 54 | 85 | 2.0 | 213.3 | 2.25 | 65.7 | 13.4 |
| 55 | 85 | 2.1 | 219.1 | 2.25 | 65.8 | 13.8 |
| 56 | 84 | 2.2 | 224.9 | 2.25 | 65.9 | 14.2 |
| 57 | 83 | 2.2 | 230.6 | 2.25 | 66.0 | 14.6 |
| 58 | 83 | 2.3 | 236.2 | 2.25 | 66.1 | 15.0 |
| 59 | 83 | 2.4 | 241.9 | 2.25 | 66.2 | 15.4 |
| 60 | 82 | 2.5 | 247.5 | 2.25 | 66.3 | 15.7 |
| 61 | 81 | 2.6 | 253.0 | 2.25 | 66.4 | 16.1 |
| 62 | 81 | 2.6 | 258.6 | 2.25 | 66.5 | 16.5 |
| 63 | 80 | 2.7 | 264.0 | 2.25 | 66.5 | 16.9 |
| 64 | 79 | 2.8 | 269.4 | 2.25 | 66.6 | 17.2 |
| 65 | 78 | 2.9 | 274.7 | 2.25 | 66.7 | 17.6 |
| 66 | 77 | 3.0 | 279.9 | 2.25 | 66.8 | 18.0 |
| 67 | 77 | 3.1 | 285.1 | 2.25 | 66.8 | 18.3 |
| 68 | 76 | 3.2 | 290.3 | 2.25 | 66.9 | 18.7 |
| 69 | 76 | 3.3 | 295.4 | 2.25 | 66.9 | 19.0 |
| 70 | 75 | 3.5 | 300.5 | 2.25 | 66.9 | 19.4 |
| 71 | 74 | 3.6 | 305.5 | 2.25 | 67.0 | 19.7 |
| 72 | 73 | 3.7 | 310.4 | 2.25 | 67.0 | 20.1 |
| 73 | 72 | 3.8 | 315.3 | 2.25 | 67.0 | 20.4 |
| 74 | 71 | 4.0 | 320.0 | 2.25 | 67.0 | 20.7 |

[1] *From the Hy-Line Brown Commercial Management Guide 2000-2001*

## Achieving Levels Of Production For Commercial Use

Experience has shown that it is quite possible to achieve the standards set by the breeding companies on a consistent basis. Cumulative eggs per Hen Housed (HH) is perhaps the single most important production parameter, and this can be achieved and exceeded by as much as 10 eggs with some flocks.

Examples of production from two commercial flocks are given in Table 2, compared against the Hy-Line Brown standards. These are from two different layer farms in Australia, during the year 2002. Housing is environmentally controlled, with temperatures held in the range 23-25°C at all times. The feed contains wheat, wheat pollard/bran, meat and bone meal, lupins, canola meal, tallow, lysine, liquid hydroxy methionine, threonine, limestone grit, sodium bicarbonate, salt, yolk pigment, phytase, xylanase, and vitamins/trace minerals.

Both these flocks have performed well, and have met the standards for cumulative eggs. Note there are some differences in egg size, feed consumption and mortality between the flocks. These differences are not necessarily strain related, but are more related to bodyweight at 16 weeks, and feed specifications.

**Table 2. Examples of production for two flocks of brown egg layers**

| | Standards | Flock 1 | Flock 2 |
|---|---|---|---|
| Strain | Hy-Line Brown | Hy-Line Brown | Isa Brown |
| Number of birds | - | 35,000 | 20,000 |
| Age at first egg, weeks | 18 | 18 | 18 |
| Age at 50% production, weeks | 21 | 20.7 | 20.8 |
| Age at Peak production, weeks | 27 | 26 | 26 |
| Maximum Hen Day Peak, % | 95 | 96.8 | 96 |
| No. of weeks over 90% | 22 | 14 | 24 |
| HH eggs cumulative | | | |
| At 74 weeks | 320 | 318 | 328 |
| At 80 weeks | 347 | - | - |
| Egg weight, grams | | | |
| At 32 weeks | 62.3 | 56.9 | 60 |
| At 70 weeks | 66.9 | 64.3 | 65 |
| From 18-74 weeks | 64.7 | 61 | 63 |
| Total Egg mass, kg | | | |
| From 18-74 weeks | 20.7 | 19.70 | 20.92 |
| From 18-80 weeks | 22.6 | - | - |
| Feed intake, grams/day | 112 | 105 | 120 |
| FCR, g feed/g egg 21-74 wks | 2.06 | 2.122 | 2.276 |
| Cum. Mortality, 18-74 wks, % | 5.0 | 2.64 | 7 |

## Using Production To Determine Nutrient Requirements

Estimates of nutrient requirements of layers are available from several sources, including NRC, breeding companies and published research. These estimates vary greatly, particularly those provided by the layer breeding companies. As a general rule, breeding companies do not conduct much research on nutritional requirements, and more likely obtain their recommendations from external sources.

In addition, most nutrient requirements figures are quite limited as to the number of essential amino acids they cover (often only lysine, sulfur amino acids, and tryptophan) and are usually expressed on a total basis, whereas I formulate on a digestible amino acid basis.

I developed my estimates on requirements initially from published research, particularly from the work of Dr Craig Coon (59th Minnesota Nutrition conference, 1998, pages 263-278), and have modified them over the years from experience with numerous flocks. I have had good access to records of many layer flocks over a 10 year period from my Australian clients. I assume that when flocks perform close to their genetic potential, their consumption of nutrients at that time is close to their requirements.

An example of this is shown in Table 3. Six flocks were selected whose total cycle production data indicated they have performed close to potential. For these flocks I have indicated in the table the minimum nutrient specs of the diet fed. The average daily consumption throughout lay (18-74 weeks) for these flocks was 110 grams. I then calculated the daily consumption of nutrients in the last column, by multiplying the minimum specs by the feed consumption. I then take this to be the nutrient requirements.

In Table 4, these requirements have been translated into minimum nutrient specs for flocks with different feed intakes.

**Table 3. Calculation of nutrient requirements**

| Nutrient | Minimum Diet Nutrient Specs | Daily Nutrient Consumption |
|---|---|---|
| Digestible Lysine | 0.700 % | 770 mg |
| Digestible Methionine | 0.350 % | 385 mg |
| Digestible M+C | 0.575 % | 633 mg |
| Digestible Tryptophan | 0.140 % | 154 mg |
| Digestible Threonine | 0.480 % | 528 mg |
| Digestible Arginine | 0.880 % | 968 mg |
| Digestible Isoleucine | 0.550 % | 605 mg |
| Digestible Valine | 0.650 % | 715 mg |
| Calcium | 3.6 % | 3.96 g |
| Available Phosphorus | 0.350 % | 385 mg |
| Sodium | 0.180 % | 198 mg |
| Linoleic acid | 1.1 % | 1.21 g |
| Choline | 1200, ppm | 1320 mg |

**Table 4. Dietary nutrient specifications for different daily intakes**

| | Daily requirement | 90 grams | 95 grams | 100 grams | 105 grams | 110 grams | 115 grams | 120 grams |
|---|---|---|---|---|---|---|---|---|
| ME, kcal/kg | 270-310 kcal | 2900 | 2850 | 2800 | 2800 | 2800 | 2750 | 2750 |
| Digest. Lysine, % | 770 mg | 0.856 | 0.810 | 0.770 | 0.733 | 0.700 | 0.670 | 0.642 |
| Digest. Methionine, % | 385 mg | 0.428 | 0.405 | 0.385 | 0.367 | 0.350 | 0.335 | 0.321 |
| Digest. M+C, % | 633 mg | 0.703 | 0.666 | 0.633 | 0.603 | 0.575 | 0.550 | 0.528 |
| Digest. Tryptophan, % | 154 mg | 0.171 | 0.162 | 0.154 | 0.147 | 0.140 | 0.134 | 0.128 |
| Digest. Threonine, % | 528 mg | 0.587 | 0.556 | 0.528 | 0.503 | 0.480 | 0.459 | 0.440 |
| Digest. Arginine, % | 968 mg | 1.076 | 1.019 | 0.968 | 0.922 | 0.880 | 0.842 | 0.807 |
| Digest. Isoleucine, % | 605 mg | 0.672 | 0.637 | 0.605 | 0.576 | 0.550 | 0.526 | 0.504 |
| Digest. Valine, % | 715 mg | 0.794 | 0.753 | 0.715 | 0.681 | 0.650 | 0.622 | 0.596 |
| Calcium, % | 3.96 g | 4.40 | 4.17 | 3.96 | 3.77 | 3.60 | 3.44 | 3.30 |
| Available Phosphorus, % | 385 mg | 0.428 | 0.405 | 0.385 | 0.367 | 0.350 | 0.335 | 0.321 |
| 0.321Sodium, % | 198 mg | 0.220 | 0.208 | 0.198 | 0.189 | 0.180 | 0.172 | 0.165 |
| Linoleic Acid, % | 1.2 g | 1.333 | 1.263 | 1.2 | 1.143 | 1.091 | 1.043 | 1.000 |
| Choline, mg/kg | 1320 | 1467 | 1389 | 1320 | 1257 | 1200 | 1148 | 1100 |

*Notes:*

1. *Numbers in the body of the table are in percent of the diet*
2. *Feed intake should be measured accurately during lay in order to formulate the correct layer feed. Feed a diet which is designed for a feed intake 5 grams below the actual intake to allow for a safety margin*
3. *Energy level of layer feed can be between 2,600-2,950 kcal ME/kg without much effect on egg production. However the energy level will influence feed intake - lower energy level will increase feed intake and vice versa. The feed intake will normally increase by 2.5-3.5 grams for every 100 kcal/kg decrease in ME. In a hot climate it is best to feed a high energy diet of 2,800 kcal/kg or higher*
4. *Phase feeding. Different feeds can be successfully fed at different phases of the lay. As the laying period progresses, some reductions in protein, amino acids and available phosphorus plus an increased level of calcium can be fed to give some reduction in feed costs and to assist with egg quality. With the high production of today's laying hen, this must be done carefully*
5. *The layer diets should be prepared as a coarse textured mash (but pellets or crumbles may also be fed to layers)*
6. *Feed at least 50% limestone in 'grit' form*

Several points should be made about this approach. Firstly the nutrients are based on my ingredient matrix, and will be somewhat different if the matrix of another nutritionist is used. Secondly it is noted that I use the minimum specs as formulated for these calculations. In a number of cases the actual levels of some nutrients will be above the minimums. Thirdly the method is only valid with “normal” feed intakes, and would be in error in a situation of high feed intake due to low house temperatures or low feed intake due to high house temperatures.

Note that no protein requirement figure is used, as this is unnecessary when the 8 limiting digestible amino acids are covered. It may be argued that there is no need to specify amino acids beyond lysine, the sulfur amino acids and tryptophan, particularly with corn-soybean meal diets. However when using a greater range of ingredients there is the possibility that threonine, arginine, isoleucine or valine can be limiting. For example threonine can be limiting in high wheat diets, and isoleucine in diets with meat and bone meal and blood meal.

For those who still formulate with total amino acids, these requirements can still be used. Total lysine requirement may be calculated by dividing digestible lysine requirement by 0.85, then other amino acids calculated in proportion.

## Achieving The Potential Production In Southeast Asia

Can the genetic potential of the modern layer be achieved on a consistent basis under the conditions of Southeast Asia? Here the same international layer strains are used, and there are no reasons why management and feed quality should limit performance. However, the high temperatures and humidity of most Southeast Asian climates definitely impose a constraint on the ability of the layer to achieve its potential. This is particularly seen in egg size, which will be 2-3 grams lower than in a temperate situation. Otherwise it should be possible to achieve the egg number standards. Factors which need to be worked on to achieve the standards are as follows:

**Pullet weights.** It is most important to meet the bodyweight standards during rearing. For brown egg layers these are 380 grams at 5 weeks and 1550 grams at 18 weeks of age (Hy-Line Brown standards), and around 1280 grams at 18 weeks for white egg strains. Failure to achieve these will negatively influence early egg size and peak egg production. In Southeast Asia, the climate tends to restrict growth and pullets are commonly underweight going into the laying house. Higher starter and grower feed specs should be used to achieve the target weights.

**Feed specs and quality.** Feed specs which are suitable for the strain and the feed intake as suggested above must be used. Using lower feed specs for the purpose of giving a lower feed cost per tonne will not allow maximum performance and will be counter productive.

**Ventilation.** High temperature and humidity are a limitation to egg production and any measures to assist, such as improved ventilation through house design, use of fans, cool drinking water etc. are all helpful.

Environmentally controlled, closed housing offers the possibility for a better environment, but high humidity severely limits the gains from this system. It is usually not possible to bring house temperature below 28°C. with such housing. If well designed, this housing does offer benefits, but they are more in the consistency of egg production and savings in labour than any large increases in egg production. When not designed well, they can be worse than open housing, with poor airflow and inadequate removal of ammonia.

**Linoleic acid.** High levels of linoleic acid in the grower and early lay periods is one way to increase early egg size, at a time when the return for small eggs is usually low. This is not so easy as the oils necessary to achieve a level of 1.3-1.5 % linoleic are usually not readily available in Asia. The best oils for this purpose are safflower or sunflower oil (60-70% linoleic), but canola and soy oil (50% linoleic) may also be used. Fullfat soy is one way of achieving these high levels. The cost of doing this should be judged against the low returns for eggs below 50 grams in size.

Delaying the onset of lay by 2 weeks with light control (in closed housing) or feed restriction is another way to increase early egg size, but the cost of doing this is a reduced egg number at 74 weeks of age.

# Feeding Programs For Laying Hens

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## Introduction

With high egg output and reduced feed intake, packaging the required nutrients into the voluntary daily intake of the layer, has become increasingly more difficult. A balance of all nutrients is required for maximum egg mass output, although of these nutrients, energy intake is often a limiting nutrient. Even under heat-stress conditions, energy needs are often the limiting factor to maintaining good egg production, and achieving optimum egg size and eggshell quality. Protein and amino acid intake is obviously critical, although it is fairly easy to maintain intake of critical amino acids even at relatively low feed intake. On the other hand, it is more difficult to maintain energy intake, and much of this challenge relates to the fact that feed intake per se is largely controlled by energy needs. The bird will, therefore, adjust its feed intake with fair precision in response to changes in diet energy level. As the energy level of the diet increases, then birds eat less and vice versa with low energy diets, so that the bird maintains a relatively constant energy intake. It is fairly difficult to convince the bird to consume amounts of energy different to its "requirement". Certainly higher-energy diets do fool the bird into eating more energy, but the response is small, and "over consumption" of energy is often quite small in relation to our expected needs for the bird. Table 1 shows diet specification for layers based on expected feed intake. There is a considerable range of daily feed intake patterns shown by laying hens, and so it is important to select and formulate diets based on expected feed intake, such that the daily intake of specified nutrients are achieved. The large range of daily feed intakes encountered with laying hens is caused by variation in age at sexual maturity, inherent body weight and environmental effects such as temperature and bird density.

**Table 1. Diet specifications for layers.**

| | Laying hens Feed intake/day (g) | | | | |
|---|---|---|---|---|---|
| | **120** | **110** | **100** | **90** | **80** |
| Approximate protein level (%) | 14.0 | 15.5 | 17.0 | 19.0 | 20.5 |
| **Amino acids (% of diet)** | | | | | |
| Arginine | 0.60 | 0.68 | 0.75 | 0.82 | 0.90 |
| Lysine | 0.56 | 0.63 | 0.70 | 0.77 | 0.84 |
| Methionine | 0.31 | 0.34 | 0.37 | 0.41 | 0.47 |
| Methionine + cystine | 0.53 | 0.58 | 0.64 | 0.71 | 0.80 |
| Tryptophan | 0.12 | 0.14 | 0.15 | 0.17 | 0.18 |
| Histidine | 0.14 | 0.15 | 0.17 | 0.19 | 0.25 |
| Leucine | 0.73 | 0.82 | 0.91 | 1.00 | 1.09 |
| Isoleucine | 0.50 | 0.57 | 0.63 | 0.69 | 0.73 |
| Phenylalanine | 0.38 | 0.42 | 0.47 | 0.52 | 0.57 |
| Phenylalanine + tyrosine | 0.65 | 0.75 | 0.83 | 0.91 | 0.99 |
| Threonine | 0.50 | 0.57 | 0.63 | 0.69 | 0.73 |
| Valine | 0.56 | 0.63 | 0.70 | 0.77 | 0.82 |
| Metabolizable energy (kcal/kg) | 2700 | 2700 | 2800 | 2850 | 2850 |
| Calcium (%) | 3.00 | 3.25 | 3.50 | 3.60 | 3.80 |
| Available phosphorous (%) | 0.35 | 0.40 | 0.40 | 0.42 | 0.45 |
| Sodium (%) | 0.17 | 0.18 | 0.18 | 0.19 | 0.20 |
| **Vitamins (per kg of diet)** | | | | | |
| Vitamin A (I.U.) | | | 7500 | | |
| Vitamin D3 (I.U.) | | | 2500 | | |
| Choline equivalents (mg) | | | 1200 | | |
| Riboflavin (mg) | | | 4.5 | | |
| Pantothenic acid (mg) | | | 10.0 | | |
| Vitamin B12 (mg) | | | 0.010 | | |
| Folic acid (mg) | | | 0.75 | | |
| Biotin (mg) | | | 0.15 | | |
| Niacin (mg) | | | 40.0 | | |
| Vitamin K (mg) | | | 2.0 | | |
| Vitamin E (I.U.) | | | 25.0 | | |
| Thiamin (mg) | | | 2.0 | | |
| Pyridoxine (mg) | | | 3.0 | | |
| **Trace minerals (per kg of diet)** | | | | | |
| Managanese (mg) | | | 70 | | |
| Iron (mg) | | | 80 | | |
| Copper (mg) | | | 8.0 | | |
| Zine (mg) | | | 60 | | |
| Selenium (mg) | | | 0.3 | | |
| Iodine (mg) | | | 0.4 | | |

Most Leghorn strains of bird will now start to mature on intakes of 80-85g/day, and it is quite difficult to formulate diets for these birds that will ensure adequate intakes of all nutrients. Meeting the bird's energy needs is perhaps most critical at this time. Through the period of peak egg numbers, it is important that the bird not be deficient in energy, and so high, rather than low energy diets are usually preferred. However, energy level can be altered within reasonable limits, and the bird will adjust its feed intake accordingly. Maintaining the balance of other nutrients to energy is therefore an important concept in layer nutrition.

## General Considerations In Feeding Layers

The development of feeding programs for layers cannot be implemented without consideration of the rearing program. Unfortunately, many egg producers purchase point-of-lay pullets from independent pullet growers, and here the goals of the two producers are not always identical. Too often, the egg producer is interested in purchasing mature pullets at the lowest possible cost per bird regardless of its condition. For pullet growers to make a profit, they must produce a bird at the lowest possible cost. With feed representing some 60 to 70% of the cost to produce a pullet, the obvious way for the pullet grower to reduce costs is to save on feed. While they may be able to save a small amount of feed by eliminating feed waste or by ensuring that house temperatures are optimum, the only way to save a substantial amount of feed is to place the pullets on a growing program such that feed consumption is reduced and/or cheaper diets are used. Because it is not possible to enhance the efficiency with which pullets convert feed into body weight gain, the net result is a smaller bird going into the laying house. If the birds have been on an increasing light pattern, they might well be mature, as judged from appearance, at the onset of production. However, such pullets must still grow before they reach their optimum weight and condition as a laying hen. Consequently, the egg producer will have to feed this pullet so as to attempt to bring the body weight up to normal if a profitable laying flock is to be obtained. If egg producers attempt to save on feed, the result will be underweight birds at peak egg production. This situation leads to smaller eggs, and often lower than normal peaks or birds dropping relatively quickly in production shortly past peak as discussed in the previous chapter.

It takes a certain amount of feed to produce a laying hen with optimum body size. If this feed is not consumed in the growing period, it must be fed in the laying house. Of course, one would have to be sure that the pullets are healthy and are not carrying an excess of body fat. However, the problem of excess body fat with today's modern type, early maturing pullet does not usually occur. Egg producers should also find out as much as possible about the pullets they are purchasing such as the type of feeding program they have been on, the health status of the flock, and the type of waterers used in rearing. With this type of information, they should be in a better position to turn the immature pullets into a profitable laying flock.

Over the last few years, it has become general practice to describe feeding programs for Leghorn birds according to the level of feed intake. It is well known that under normal environmental and management conditions, feed intake will vary with the egg production and/or age of bird, and this must be taken into account when formulating diets. While Leghorn may adjust intake according to diet energy levels, there is no evidence to suggest that such precision occurs with other nutrients.

The following daily intakes of nutrients are suggested under ideal management and environmental conditions (Table 2).

**Table 2. Daily nutrient recommendations**

| | |
|---|---|
| Crude protein | 17g |
| Metabolizable energy | 280 kcal |
| Methionine | 360 mg |
| Methionine + Cystine | 640 mg |
| Lysine | 720 mg |
| Calcium | 3.5 g |
| Available phosphorus | 0.4 g |
| Sodium | 0.18 g |

However, as feed intake changes, specifications must be modified in order to maintain this intake of nutrients. Table 3 gives an example of the type of specification changes necessary for various levels of feed intake. As a generalization, these changes are something of a compromise, since it is often difficult and uneconomical to go to the extreme specifications necessary with very low levels of feed intake. A knowledge of feed intake, and the factors that influence it, are therefore essential for any feed management program.

**Table 3. Diet specifications and daily feed intake**

| | 110g | 100g | 90g | 80g | 70g |
|---|---|---|---|---|---|
| Crude protein equivalent (%) | 15.5 | 17.0 | 19.0 | 20.5 | 22.1 |
| Metabolizable energy (kcal/kg) | 2700 | 2800 | 2915 | 3025 | 3080 |
| Calcium (%) | 3.4 | 3.5 | 3.6 | 3.8 | 4.0 |
| Available phosphorus (%) | .38 | .40 | .45 | .50 | .55 |
| **Amino acids (%)** | | | | | |
| Lysine | .68 | .72 | .77 | .84 | .91 |
| Methionine | .32 | .36 | .41 | .47 | .56 |
| Methionine + Cystine | .55 | .64 | .71 | .80 | .91 |
| Tryptophan | .14 | .15 | .17 | .18 | .20 |

To a degree, the energy level of the diet will influence feed intake, although one should not assume the precision of this mechanism to be perfect. In general, birds over consume energy with higher energy diets, and they will have difficulty maintaining normal energy intake when diets of less than 2500 kcal ME/kg are offered. In most instances, under consumption rather than over-consumption is the problem, and so use of higher energy diets during situations such as heat stress will help to minimize energy insufficiency.

There is little doubt that body weight at maturity is a major factor influencing feed intake and so economic performance of laying hens. Body weight differences seen at maturity are maintained throughout the laying cycle almost regardless of nutrient profile of layer diets. It is therefore difficult to attain satisfactory nutrient intakes with small birds. Conversely, larger birds will tend to eat more, and this may become problematic in terms of the potential for obesity and/or too large an egg towards the end of lay. Phase feeding of nutrients can overcome some of these problems, although a more simplistic long term solution is control over body weight at maturity. Under most economic conditions, heavier birds at maturity are ultimately most economical for table egg production in terms of egg revenue relative to feed costs.

This whole situation of feed management is also being confounded with earlier and higher peaks from today's strains of birds. Under these "ideal" situations, it is again energy insufficiency that can cause problems during post peak production. Egg production curves that show a 5 - 8% reduction after peak are characteristic of birds with insufficient appetite caused by too small a pullet at maturity. The reduction in appetite is of concern relative to the adequacy of energy intake. Calculations of energy balance indicate a somewhat precarious balance around the time of peak egg numbers, indicating the need for stimulating feed intake per se, and the possibility of providing some labile energy reserves in the form of carcass energy (fat) stores. Tables 3 and 4 show such calculated values for Leghorn and brown egg strains respectively, and relate these to the required intake of a standard diet.

**Table 3. Energy balance of Leghorn pullets during early egg production**

| | Theoretical Daily Energy Requirement (kcal ME per bird) | | | | | |
|---|---|---|---|---|---|---|
| Weeks Age | Maintenance | +20% Activity Allowance | Growth | Eggs | Total | Required intake of 17% CP, 2850 ME diet (g/d) |
| 16 | 111 | 133 | 43.7 | - | 177 | 62 |
| 17 | 114 | 137 | 43.7 | - | 181 | 64 |
| 18 | 118 | 142 | 43.7 | - | 186 | 65 |
| 19 | 122 | 146 | 43.7 | - | 190 | 67 |
| 20 | 125 | 150 | 43.7 | 5.0 | 199 | 70 |
| 21 | 129 | 155 | 43.7 | 10.0 | 209 | 73 |
| 22 | 132 | 158 | 43.7 | 24.0 | 227 | 80 |
| 23 | 136 | 163 | 43.7 | 42.6 | 250 | 88 |
| 24 | 139 | 167 | 43.7 | 60.9 | 272 | 95 |
| 25 | 141 | 169 | 43.7 | 77.8 | 269 | 94 |
| 26 | 142 | 170 | 21.9 | 84.9 | 277 | 97 |
| 27 | 146 | 175 | 21.9 | 87.1 | 284 | 100 |
| 28 | 147 | 176 | 21.9 | 88.6 | 286 | 100 |
| 29 | 149 | 179 | 21.9 | 89.6 | 291 | 102 |
| 30 | 150 | 180 | 21.9 | 90.7 | 293 | 103 |

The significance of energy intake as the limiting nutrient for egg production with modern strains of layer is shown in (Figure 1). There is a dramatic response to energy intake from 184-312 kcal/bird/day, in the form of egg output. At very high energy intakes, there is little apparent response to protein intake over the range of 13 - 21 g /bird/day.

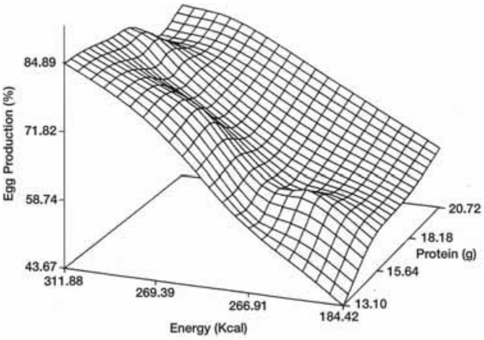
Only when energy intake is limiting is there any measurable increase in egg numbers in response to increased protein intake. However, as will be detailed later, the converse applies in terms of egg size, when the bird shows a dramatic response to protein intake and little response to energy intake. Many problems associated with reduced nutrient intake of white egg layers can therefore be overcome by ensuring optimum body weight and appetite of young laying pullets.

**Table 4. Energy balance of brown egg pullets during early egg production (kcal/bird)**

| | Theoretical Daily Energy Requirement (kcal ME per bird) | | | | | |
|---|---|---|---|---|---|---|
| Weeks Age | Maintenance | +15% Activity Allowance | Growth | Eggs | Total | Required intake of 17% CP, 2850 ME diet (g/d) |
| 16 | 128 | 147 | 80 | - | 227 | 80 |
| 17 | 131 | 151 | 80 | - | 231 | 81 |
| 18 | 136 | 156 | 80 | - | 236 | 83 |
| 19 | 140 | 161 | 80 | 2 | 243 | 85 |
| 20 | 144 | 166 | 80 | 8 | 254 | 59 |
| 21 | 148 | 170 | 70 | 61 | 301 | 106 |
| 22 | 152 | 175 | 70 | 66 | 309 | 108 |
| 23 | 156 | 179 | 55 | 83 | 315 | 111 |
| 24 | 160 | 184 | 40 | 94 | 320 | 112 |
| 25 | 162 | 185 | 40 | 95 | 320 | 112 |
| 26 | 164 | 186 | 40 | 96 | 322 | 113 |
| 27 | 166 | 191 | 38 | 97 | 326 | 114 |
| 28 | 170 | 196 | 34 | 98 | 328 | 115 |
| 29 | 171 | 197 | 34 | 99 | 330 | 116 |
| 30 | 172 | 198 | 32 | 100 | 330 | 116 |

Unfortunately, mean weight of the flock at this age is too often considered independently of flock uniformity. Pullets may be of “mean” body weight, yet be quite variable in weight, and often outside the accepted range of 85% of the flock being within +-10% of mean weight. The major problem with a nonuniform flock is variability in age at first egg, and so there is variability in feed intake. If diets are tailored to feed intake, then late maturing smaller birds (with small appetites) will likely be underfed. Conversely, large weight early maturing pullets with increased appetites may be overfed at this time. The consequence is often a delayed peak, and reduced overall egg production.

**Figure 1. Egg production (18–66 weeks) in response to intakes of energy and protein.**



An argument against being overly concerned about uniformity is that birds will adjust their intake according to nutrient (energy) needs, and so early maturing birds will eat more, and late maturing birds less, during the early phases of production. However, if birds are given diets formulated on the basis of feed intake, this can lead to problems, the most serious of which is underfeeding of the larger early maturing bird. Another confounding factor, is that as birds mature within a flock, the percent production realized on a daily basis does not reflect the number of birds laying at that time. For example at about 40% production, there are in fact around 70% of the birds mature and requiring proportionally more nutrients than suggested by egg production alone. These differences become more pronounced as flock uniformity declines, and so this makes tailoring nutrient needs to feed intake and performance characteristics that much more difficult to achieve.

## Heat Stress

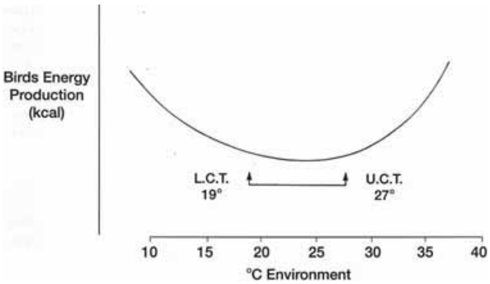
An increasingly large proportion of the world’s laying hens are kept in areas where heat stress is likely to be a major management factor at some stage during egg production. Basically the problem relates to birds not consuming enough feed at this time, although there are also some subtle changes in the bird’s metabolism that affect both production and shell quality. While all types of poultry thrive in warm environments during the first few weeks of life, normal growth and development of older birds is often adversely affected. Obviously, the bird’s requirements for supplemental heat declines with age, because insulating feathers quickly develop and surface area in relation to body size is reduced. Heat stress is often used to describe bird status in hot environments, although it is obvious that more than just temperature is involved. Because birds must use evaporative cooling (as panting) to lose heat at high temperatures, humidity of inhaled air becomes critical. Thus high temperature and humidity together are much more stressful to birds than high temperature alone. Other environmental factors such as air speed and air movement also become important. It is also becoming clear that adaptation to heat stress can markedly influence bird response. For example, laying birds can tolerate constant environmental temperatures of 35°C and perform reasonably well. On the other hand, most birds are stressed at 35°C when fluctuating day/night temperatures are involved. In the following discussion, it is assumed that fluctuating conditions exist, since these are more common and certainly more stressful to the bird.

The main concern under hot weather conditions is the layer’s ability to consume feed. As poultry house temperature increases, then less heat is required to maintain body temperature and the birds consume less feed. In this situation, “environmental” energy is replacing feed energy and is economical. However, the relationship between body heat production and house temperature is not linear, since at a certain critical temperature, the bird’s energy demands are increased in order to initiate body cooling mechanisms. The following factors should be considered in attempting to accommodate heat stress.

### *A. Bird’s Response To Heat Stress*

Figure 2 is a schematic representation of a heat stress effect. Minimal body heat production (and hence the most efficient situation) is seen at around 23°C. Below this temperature, (lower critical temperature) birds generally have to generate more body heat in order to keep warm.

Figure 2. Environmental temperature and body heat production.



However, there is only a narrow range of efficiency between 19-27°C, over which heat production is minimal. Above 27°C, birds start to use more energy in an attempt to stay cool. For example, at 27°C, birds will start to dilate certain blood vessels in order to get more blood to the comb, wattles, feet etc. in an attempt to increase cooling capacity. More easily observed by the egg producer is the characteristic panting and wing drooping that occurs at slightly higher temperatures. These activities at high environmental temperatures mean that the bird has an increased, rather than decreased, demand for energy. Unfortunately, the situation is not as clear cut as depicted in Figure 2, and this is likely the reason behind the variability seen in flock response to various environmental conditions. Rather than lower and upper critical temperature being rigidly fixed under all conditions, heat production is likely to fluctuate in response to a number of very practical on-farm conditions. Variation in response can be caused by such factors as a) increased feed intake, b) better feathering or c) increased bird activity. Such potential variability in bird response should be taken into account when interpreting the quantitative data discussed in Figures 3 and 4. The whole picture is further confused by the normal energy intake pattern of the bird (Figure 3). The base line shown in Figure 3 is a repeat of the temperature effect detailed in Figure 2.

The upper line of Figure 3 represents energy intake for a 1.5 kg layer. Again as environmental temperature increases, energy (feed) intake declines. However above 27-28°C, the decline becomes quite dramatic since the bird is changing its metabolic processes in response to the heat load, and actions such as panting, etc. adversely influence the feeding mechanisms in the brain and also reduce the time available for feeding. The shaded area between the lines in Figure 3, represents the energy available for production. As we approach and exceed the critical 28°C mark, then energy available for production is dramatically reduced and around 33°C actually becomes negative.

If the shaded area (available energy), in Figure 3 is itself plotted against temperature, then a clear pattern is seen with respect to potential for egg production (Figure 4). If we assume an average egg contains the equivalent of 80 kcal ME, then at 90% production, there is a daily need for around 70 kcal to meet needs for production alone. Our calculations from Figure 3 indicate total available energy at 90 kcal per day, and so we have a small positive difference that will likely go for growth or increased body weight. At 28°C, there is energy available only for eggs and none for growth. Above 28°C, available energy cannot meet energy demands for 90% egg production. Either egg production must be decreased, or other energy sources used. The bird's body reserves (fat and muscle) could therefore be used at this time. These figures are not fixed and will likely vary with such factors as air speed, feathering etc. as previously detailed. However, for most flocks, these types of reactions, as depicted in Figure 4 are likely to occur at + 2°C of the values shown. In this scenario, the bird is in negative energy balance at 33°C (Figure 4). Various equations have been developed to relate energy intake to environmental temperature. For example, the equations given by NRC (1994) is ME(kcal/day)

Figure 3. Environmental temperature and energy balance.

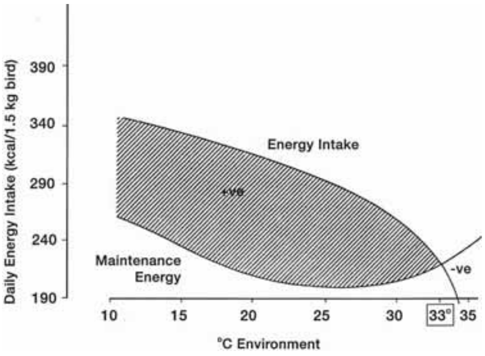
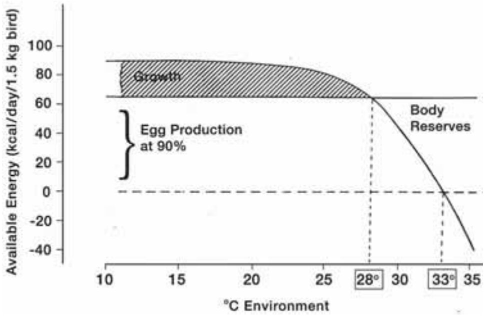


Figure 4. Environmental temperature and energy balance.



= W75 (173 - 1.95T) + 5.5 W + 2.07EE where W = body weight, kg; T = C, W = weight gain per day, g; and EE = daily egg mass, g. Solving this equation for environmental temperatures of 10-34°'a1C, shows an almost linear relationship for a 1.3 kg bird producing 50 g egg mass per day and gaining weight at 2 g per day (Fig. 5).

A major factor affecting this energy intake response to environmental temperature is feather cover, which represents insulating capacity for the bird. Coon and co-workers have developed equations that take into account degree of feathering. This equation is solved in Figure 6 for birds having 90, 75 or 60% feather cover. As expected, at low environmental temperatures, feather cover has a major effect on feed intake, while at 34°C which is close to body temperature; there is no effect of feather cover.

**Figure 5. ME intake of layers predicyed between 10-34°C (NRC, 1994).**

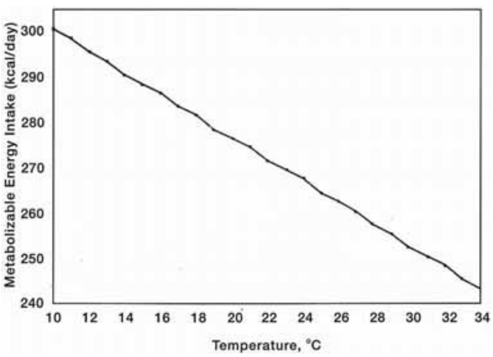
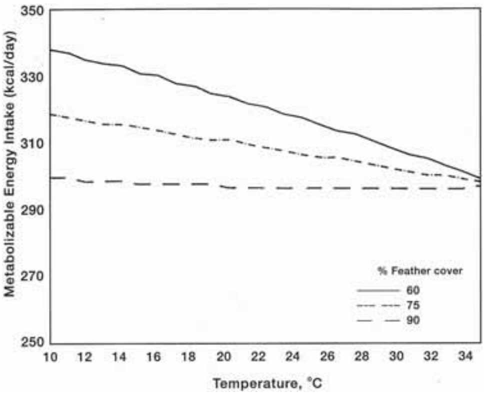


**Figure 6. ME intake of layers with 60, 75 or 90% feather cover at 10-34°C (Paguri and Coon, 1995).**



### *B. Energy Balance*

Our main concern during heat stress therefore is the availability of energy for egg production. Optimizing such energy availability may be approached by either:

***(i) Increasing diet energyspecifications***
***(ii) Stimulating feed intake or***
***(iii) Considering body energy reserves***

(i) It is well known that birds consume less feed as the energy level of the feed increases. This is because the bird attempts to maintain a given energy intake each day. However, the mechanism is by no means perfect, and as energy level is increased, the expected decline in feed intake is seldom achieved. This obviously leads to "overconsumption" of energy. Also, as environmental temperature increases, the mechanism seems less perfect. The following results are seen when diet energy level is increased from 2860 kcal ME/kg to 3450 kcal ME/kg (Table 5, Payne, 1967).

At 18°C, there is fairly good adjustment by the bird, such that feed intake is markedly reduced with high energy diets; this in an attempt to normalize energy intake. At high temperatures, birds adjust feed intake less perfectly, such that "overconsumption" of energy occurs. It is not suggested that these extremes of diet energy be used, rather that energy intake will be maximized with as high a diet energy level as is possible. In order to increase diet energy level, the use of supplemental fat should be considered. Dietary fat has the advantage of increasing palatability and also reducing the amount of heat increment that is produced during its utilization in the body.

**Table 5. Effect of diet energy level on metabolizable energy intake**

| | at 18°C | | at 30°C | |
|---|---|---|---|---|
| Diet energy (kcal ME/kg) | Feed per day (g) | Energy per day (kcal) | Feed per day (g) | Energy per day (kcal) |
| 2860 | 127 | 363 | 107 | 306 |
| 3060 | 118 | 360 | 104 | 320 |
| 3250 | 112 | 364 | 102 | 330 |
| 3450 | 106 | 365 | 101 | 350 |

*(From Payme 1967)*

(ii) Various methods can be tried to stimulate feed intake. Feeding more times each day usually encourages feeding activity. Feeding at cooler times of the day, if possible, is also a useful method of increasing nutrient intake. If artificial lights are used, it may be useful, under extreme environmental conditions, to consider a so-called midnight feeding, when temperature will hopefully be lower and birds are more inclined to eat. Again, where conditions are extreme, making the diet more palatable may be advantageous. Such practices as pouring vegetable oil, molasses, or even water, directly onto the feed in the troughs may encourage intake. Whenever high levels of fat are used in a diet, or used as a top dressing as described here, care must be taken to ensure that rancidity does not occur. This can best be achieved by insisting on the incorporation of quality antioxidants in the feed and that feed is not allowed to "cake" in tanks, augers or troughs. Fresh feed becomes critical under these conditions.

Diet texture can also be used to advantage. Crumbles tend to stimulate intake while a sudden change from large to small crumbles also has a transitory effect on stimulating intake. It is interesting to observe that a sudden change from small to large crumbles seems to have a negative effect on intake (Table 6).

**Table 6. Effect of sudden change in feed particle size on feed intake (5-7d) following this change.**

| | Regular crumbs | Only small crumbs <2.4 mm | Only large crumbs >2.4 mm |
|---|---|---|---|
| Feed (g/bird/day) | $112^b$ | $124^a$ | $81^c$ |

*$^{a\text{-}c}$ means followed by different letters are significantly different*

(iii) It is now realized that correct pullet rearing programs are essential for optimum economic return in the layer house. This becomes very critical under hot weather conditions as the bird may have to rely on its body reserves to supplement energy required to maintain egg production. In general, the larger the body weight at maturity, the larger the body weight throughout lay, and hence the larger the potential energy reserve and the greater the feed intake.

It is not suggested that extremely fat pullets are desirable, but it is obvious that birds of optimum weight with a reasonable fat reserve will likely stand up better to heat stress situations. Pullets that are subjected to heat-stress and have less "available" energy than that required to sustain production, have no recourse but to reduce egg mass output in terms of egg weight and/or egg numbers.

### *C. Protein Nutrition*

In the past, it has been common practice to increase protein levels during heat stress conditions. This has been done on the basis of reduced feed intake, and hence protein levels have been adjusted upwards in attempting to maintain intakes of around 17g crude protein/bird/day. It is now realized that such adjustments may be harmful. When any nutrient is metabolized in the body, the processes are not 100% efficient and as a result, some heat is produced. Unfortunately, protein is the most inefficiently utilized nutrient in this regard and so proportionately; more heat is evolved during metabolism of amino acids. The last thing that a heat stressed bird needs is additional waste heat being generated in the body. This extra heat production may well overload heat dissipation mechanisms (panting, blood circulation). We are therefore faced with a difficult problem of attempting to maintain "protein" intake in situations of reduced feed intake, yet we know that more crude protein may be detrimental. The answer to the problem is not to increase crude protein, but rather to increase the levels of essential amino acids. By feeding synthetic amino acids, we can therefore maintain the intake of these essential nutrients without loading up the body systems with excess crude protein (nitrogen). General recommendations are, therefore, to increase the use of synthetic methionine and lysine so as to maintain daily intakes of approximately 360 and 720mg respectively.

### *D. Minerals And Vitamins*

Calcium level should be adjusted according to anticipated level of feed intake, such that birds consume 3.5g per day. Under extreme conditions, this may be difficult since, as previously indicated, high energy diets are also desirable and these are difficult to achieve with the increased use of limestone or oyster shell. Table 7 shows the diet specifications needed to maintain intakes of Ca, P and vitamin D3, all of which are critical for eggshell quality.

Because it is also necessary to increase the energy level of the diet when feed intake is low, then it is counterproductive to add high levels of limestone and phosphates which effectively dilute the feed of all nutrients other than Ca and phosphorus. The problem of potential calcium deficiency is

**Table 7. Diet nutrient levels needed to maintain constant intake at varying levels of feed intake**

| Feed intake (g/d) | av P (%) | Ca (%) | Vit D3, (IU/kg) |
|---|---|---|---|
| 70 | 0.60 | 5.35 | 4700 |
| 80 | 0.52 | 4.68 | 4125 |
| 90 | 0.47 | 4.17 | 3660 |
| 100 | 0.42 | 3.75 | 3300 |
| 110 | 0.38 | 3.41 | 3000 |

most often met by top dressing feed with oystershell or large particle limestone. The situation for phosphorus is more complex, and in fact it may be deleterious to use the high levels shown in Table 7. In practice, phosphorus levels are seldom increased to these extreme levels unless cage layer fatigue is an ongoing problem. The deficit of vitamin D3 is best met with use of D3 supplements in the drinking water.

There seems to be some benefit to adding sodium bicarbonate to the diet or drinking water. However, this must be done with care so as not to impose too high a load of sodium on the bird, and so salt levels may have to be altered. This should be done with great caution, taking into account sodium intake from the drinking water, which can be quite high during heat stress conditions. There is also an indication of beneficial effects of increasing the potassium levels in the diet, although again, this must be accomplished only after careful calculation, since high levels can be detrimental to electrolyte balance. While few reports indicate any improvement in adding supplemental B vitamins during heat stress, there are variable reports of the beneficial effects with the fat soluble vitamins. Although not always conclusive, increasing the levels of vitamins A, D3 and E have all been shown to be advantageous under certain conditions. While vitamin C (ascorbic acid) is not usually considered in poultry diets, there is evidence to support its use during hot weather conditions. Birds require vitamin C, but under most circumstances are able to synthesize enough in their own bodies. Under heat stress, such production may be inadequate and/or impaired. Adding up to 200 mg vitamin C/kg diet has proven beneficial for layers in terms of maintaining production.

### *E. Electrolyte Balance*

As environmental temperature increases, birds increase their respiration rate in an attempt to increase the rate of evaporative cooling. As birds pant however, they tend to lose proportionally more CO2 and so changes in acid-base balance can quickly develop. With mild through to severe alkalosis, blood pH may change from 7.2 through 7.5 to 7.7 in extreme situations. This change in blood pH, together with loss of bicarbonate ions can influence eggshell quality and general bird health and metabolism. Under such heat stress conditions, it is the availability of bicarbonate per se which seems to be the major factor influencing eggshell thickness, and in turn, this is governed by acid-base balance, kidney function and respiration rate.

Under normal conditions, shell formation induces a renal acidosis related to the total resorption of filtered bicarbonate. At the same time, shell secretion induces a metabolic acidosis because the formation of insoluble CaCO3 from HCO3 - and Ca++ involves the liberation of H+ ions. Such H+ release would induce very acidic and physiologically destructive conditions, and is necessarily balanced by the bicarbonate buffer system in the fluid of the uterus. While a mild metabolic acidosis is therefore normal during shell synthesis, a more severe situation leads to reduced shell production because of intense competition for HCO3 -, as either a buffer or a shell component. A severe metabolic acidosis can be induced by feeding products such as NH4C1, and this results in reduced shell strength. In this scenario, it is likely that NH4 + rather than C1 is problematic because formation of urea in the liver (from NH4 +) again needs to be buffered with HCO3 + ions, creating more competition with uterine bicarbonate metabolism. Conversely, feeding sodium bicarbonate, especially when C1 levels are minimized, may well improve shell thickness. Under commercial conditions, the need to produce base excess in order to buffer any diet electrolytes must be avoided. Likewise it is important that birds not be subjected to severe respiratory excess, as occurs at high temperatures, because this lowers blood bicarbonate levels, and in extreme cases, causes a metabolic acidosis. Under practical conditions, replacement of part of the supplemental dietary NaC1 with NaHCO3 may be beneficial for shell production.

Acclimatization to heat stress is a confounding factor, because temporary acute conditions are more problematic. For example, pullets grown to 31 weeks under constant 35 versus 21°C conditions exhibit little difference in pattern of plasma electrolytes. If birds are allowed to acclimatize to high environmental temperatures, there is little correlation between plasma electrolytes and shell quality. Temporary acute heat stress and cyclic temperature conditions seem most stressful to the bird.

Prevention of electrolyte imbalance should obviously be approached through incorporation of appropriate cations and anions in diet formulations. However it must be accepted that diet is only one factor influencing potential imbalance, and so general bird management and welfare also become of prime importance. Electrolyte balance is most usually accommodated by consideration of Na+K-C1 balance in the diet, and under most dietary situations this seems a reasonable simplification. Electrolyte balance is usually expressed in terms of mEq of the various electrolytes, and for an individual electrolyte this is calculated as Mwt ÷ 1000. This unit is used on the basis that most minerals are present at a relatively low level in feeds. As an example calculation, the mEq for a diet containing 0.17% Na, 0.80%K and 0.22% C1 can be developed as follows:

**Sodium** Mwt = 23.0, $\therefore$ Eq = 23g/kg,
$\therefore$ MEq = 23 mg/kg
Diet contains 0.17% Na = 1700 mg/kg =
$\frac{1700}{23}$ mEq = 73.9 mEq.

**Potassium** Mwt = 39.1, $\therefore$ Ea = 39.1g/kg,
$\therefore$ MEq = 39.1 mg/kg
Diet contains 0.80% K = 8000 mg/kg =
$\frac{8{,}000}{39.1}$ mEq = 204.6 mEq

**Chloride** Mwt = 35.5, $\therefore$ Eq = 35.5 g/kg.
$\therefore$ MEq = 35.5 mg/kg
Diet contains 0.22% C1 = 2200 mg/kg, =
$\frac{2200}{35.5}$ mEq = 62.0 mEq
$\therefore$ overall diet balance becomes Na + K - C1
= 73.9 + 204.6 - 62.0 = 216.5 mEq.

A balance of around 250 mEq/kg is usual, and so for this diet there needs to be either an increase in Na or K level of the diet, or a decrease in C1 level.

Under practical conditions, electrolyte balance seems to be more problematic when chloride levels are high. On the other hand, use of NaHCO3 to replace NaC1, as is sometimes recommended during heat stress, can lead to a deficiency of chloride. Changes in diet electrolyte balance most commonly occur when there is a major change in ingredient usage, and especially when animal protein sources replace soybean meal and vice versa. Table 8 outlines electrolyte content and electrolyte balance of some major feed ingredients.

**Table 8. Electrolyte content of feed ingredients**

| | % of ingredient | | | |
|---|---|---|---|---|
| **ingredient** | **Na** | **K** | **C1** | **Na+K-C1 (mEq)** |
| Corn | 0.05 | 0.38 | 0.04 | 108 |
| Wheat | 0.09 | 0.52 | 0.08 | 150 |
| Milo | 0.04 | 0.34 | 0.08 | 82 |
| Soybean meal | 0.05 | 2.61 | 0.05 | 675 |
| Canola meal | 0.09 | 1.47 | 0.05 | 400 |
| Meat meal | 0.55 | 1.23 | 0.90 | 300 |
| Fish meal | 0.47 | 0.72 | 0.55 | 230 |
| Cottonseed meal | 0.05 | 1.20 | 0.03 | 320 |

Within the cereals, electrolyte balance for milo is low, while wheat is high relative to corn. Major differences occur in the protein-rich ingredients, and relative to soy, all sources are low in electrolyte balance. As shown in Table 8, this situation develops due to the very high potassium content of soybean meal. Careful consideration to electrolyte balance must therefore be given when changes are made in protein sources used in formulation. For example, the overall balance for a diet containing 60% milo and 25% soy is 210 mEq/kg, while for a diet containing 75% milo and 10% fish meal the balance is only 75 mEq/kg. The milo-fish diet would perhaps need to be supplemented with NaHCO3.

Assuming that heat stress cannot be tempered by normal management techniques, then electrolyte manipulation of the diet may be beneficial. However, the technique should be different for immature birds compared to egg layers. With adult female birds, there is a need to maintain the bicarbonate buffer system as it relates to eggshell quality. As such, diet or water treatment with sodium bicarbonate may be beneficial again emphasizing the necessity to meet minimal chloride requirements. On the other hand, treatment of respiratory alkalosis in layers, with acidifiers such as NH4C1 while relieving respiratory distress, may well result in reduced shell quality. For immature pullets treatment with electrolytes is often beneficial and there is less need for caution related to bicarbonate buffering. Up to 0.3% dietary NH4C1 may improve the growth rate of heat stressed birds, although as detailed previously, it is not clear if this beneficial effect is via electrolyte balance/blood pH or simply via the indirect effect of stimulating water intake. Under commercial conditions, adding salt to the drinking water of young birds has been reported to alleviate bird distress and to stimulate growth.

### *F. Water*

A nutritional factor often overlooked during heat stress is the metabolism of water. It is well known that birds in hot environments drink more water, yet this has not been capitalized upon to any degree. It would seem logical to provide nutrients in the water, because water intake is increased at times when feed intake is depressed. Unfortunately, we have only met with very limited success to date with this type of management. What does seem more advantageous is to cool the water of laying hens. In studies with small numbers of birds, we have shown a distinct advantage to cooling the drinking water of birds housed in very warm environments. In a more large scale study in a commercial unit in California, Bell (personal communication) indicates improved feed intake and egg production in response to the cooling of water by just 5°C at an environmental temperature of 32°C (Table 9). Another factor to consider with water intake, is the possible effect of dissolved minerals and contaminants, etc., the effects of which may be greatly accentuated with increase drinking activity. In terms of mineral content, sodium concentration is the one most likely to cause problems.

**Table 9. Effect of water temperature on egg production (%)**

| | Environmental temperature 32°C | |
|---|---|---|
| Age (wks) | Water at 32°C | Water at 27°C |
| 25 | 64 | 74 |
| 26 | 74 | 79 |
| 27 | 77 | 86 |
| 28 | 76 | 84 |
| 29 | 88 | 93 |
| Mean | 76 | 83 |
| Feed intake (g/b/d) | 83g | 90g |

*Bell (1987)*

### *G. General Recommendations Concerning Heat Stress*

Under normal conditions, birds should be fed so as to attain optimum daily intakes of essential nutrients. Regardless of environment, the correct decisions cannot be made without knowledge gained from the monitoring of feed intake, body weight and egg weight. With heat stress situations (28- 40°C), the following points should be considered:

1. Never place underweight pullets in the laying house. They will always remain small with low feed intake and have little body fat reserve to sustain optimum egg production.

2. Increase the energy level of the diet (2850 Kcal ME/kg minimum) ideally by incorporation of fats or oils. Limit the use of fibrous ingredients if possible.

3. Reduce crude protein component (17% CP maximum) while maintaining daily intakes of methionine (360 mg) and lysine (720mg).

4. Increase mineral-vitamin premix in accord with anticipated change in feed intake. Maintain daily intakes of calcium (3.5g) and available phosphorus (400 mg).

5. Where shell quality is a problem, consider the incorporation of sodium bicarbonate. At this time, monitor total sodium intake, and ensure adequate chloride levels in the diet.

6. Use supplemental vitamin C (150 g/tonne) when heat stress occurs.

7. Increase the number of feedings per day and try to feed at cooler times of the day.

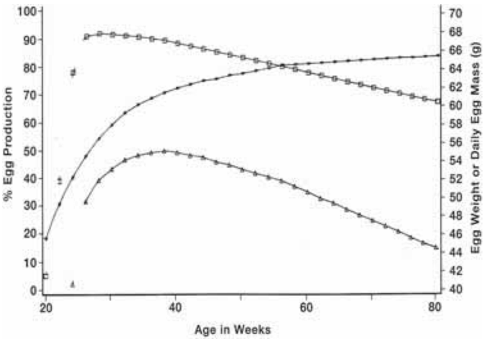
8. Keep drinking water as cool as possible. Analyze sodium content of water so as to calculate “salt” contribution from the water.

9. Use crumbled feed or large particle mash feed if available.

10. Do not make any diet changes when sudden short term (3 - 5 days) heat stress occurs.

## Phase Feeding

Figure 7. Bird age: egg production, egg weight and egg mass.



Phase feeding refers essentially to reductions in the protein and amino acid level of the diet as the bird progresses through a laying cycle. The concept of phase feeding is based on the fact that as birds get older their feed intake increases, while their egg production decreases. For this reason, it should be economical to reduce the nutrient concentration of the diet. At this time, it is pertinent to consider a conventional egg production curve of a layer, and superimpose both egg weight and daily egg mass output (Figure 7). If nutrient density is to be reduced, this should not occur immediately after peak egg numbers, but rather after peak egg mass has been achieved. There are two reasons for reducing the level of dietary protein and amino acids during the latter stages of egg production namely, to reduce feed costs and secondly, to reduce egg size. The advantages of the first point are readily apparent if protein costs are high, but the advantages of the second point are not so easily defined and will vary depending upon the price of eggs. When a producer is being paid a premium for extra large and jumbo eggs, there is no advantage to using a phase feeding program unless egg shell quality is a problem.

It is difficult to give specific recommendations as to the decrease in dietary protein level that can be made to reduce egg size without decreasing the level of production. The appropriate reduction in protein level will depend on the season of the year (effect of temperature on feed consumption), age and production of the bird, and energy level of the diet. Hence, it is necessary that every flock be considered on an individual basis before a decision is made to reduce the level of dietary protein. As a guide, it is recommended that protein intake be reduced from 17g/day to 16g/day after the birds have dropped to 80% production, and to 15g/day after they have dropped to 70% production. With an average feed intake of 100 g/day, this would be equivalent to diets containing 17, 16 and 15% protein. It must be stressed that these values should be used only as a guide after all other factors have been properly considered. If a reduction in the level of protein is made and egg production drops, then the decrease in intake has been too severe and it should be immediately increased. If, on the other hand, production is held constant and egg size is not reduced then the decrease in protein intake has not been severe enough and it can be reduced still further. The amino acid to be considered in this exercise is methionine, since this is the amino acid that has the greatest effect on egg size. Phase feeding of phosphorus has also been recommended as a method of halting the decline in shell quality often seen with older birds. Using this technique, available phosphorus levels may be reduced from approximately 0.4% at peak production to slightly less than 0.3% at the end of lay. Table 10 shows an example of phase feeding of protein, methionine and phosphorus, related to egg production, and independent of feed intake.

A major criticism of phase feeding is that birds do not actually lay “percentages” of an egg. For example, if a flock of birds is producing at 75% production, does this mean that 100% of the flock is laying at 75% or is 75% of the flock laying at 100% production? If the latter is true, then the concept of phase feeding may be harmful. If a bird lays an egg on a specific day, it can be argued that its production is 100% for that day, and so its nutrient requirements are the same regardless of the age of bird. Alternatively, it can be argued that many of the nutrients in an egg, and especially the yolk, accumulate over a number of days, and so this concept of 100% production, regardless of age, is misleading.

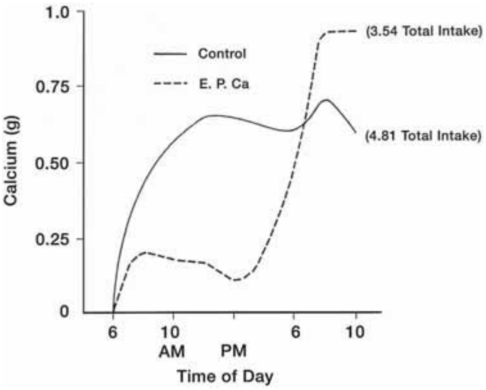
Advocates of phase feeding indicate that birds can be successfully managed by reducing protein/amino acid contents of the diet-others suggest that nutrient specifications are too high to start with initially, and that phase feeding merely accomplishes normalization of diet in relation to requirement. The bottom line is that environmental and management conditions vary from flock to flock, and certainly from season to season within a flock. For this reason, the basis of phase feeding must be an accurate assessment of the nutrient intake relative to requirement for production, growth and maintenance.

## Nutrition And Shell Quality

The laying diets shown in Table 1 contain all the calcium needed by the layer under most conditions. However, if egg shell quality is a problem during hot weather, or if the pullets have come into production at a fairly young age and have peaked very quickly, it may be advisable to increase the levels of calcium by at least 0.4%. Research has indicated that a marked improvement in shell quality can be obtained by feeding part of the dietary calcium as oyster shell or limestone chips. This is especially true if limestone flour rather than a granular source of limestone is used. The hen's requirement for calcium is relatively low, except at the time of the day when egg shell formation is taking place. The greatest rate of shell deposition occurs in the dark phase, when birds are not actively eating feed. The source of calcium during this period then becomes residual feed in the digestive tract and the labile medullary bone reserve.

In the first six hours of the 24h laying cycle, there is virtually no shell deposition. This is the time of albumen and shell membrane secretion, and the time of redeposition of medullary bone. From six to 12 hours, about 400 mg calcium are deposited, while the most active period is the 12-18 hr period when around 800 mg shell calcium accumulates.

**Figure 8. Calsium intake on egg-foring days (Chah, 1972).**

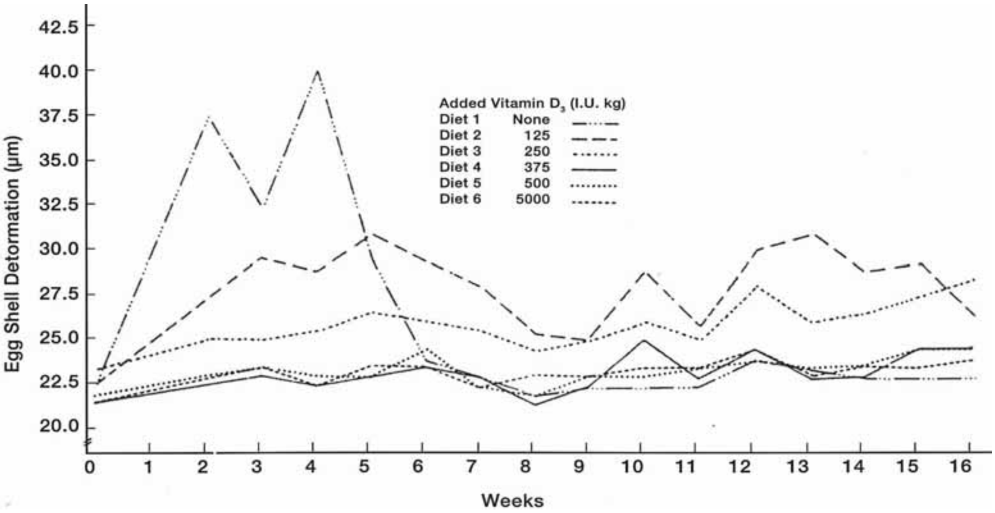


This is followed by a slower deposition of about 500 mg in the last six hours, for a total of around 1.7g shell calcium, depending upon egg size. The voluntary intake of oyster shell or large particle calcium at various times during a normal 16h day is shown in Figure 8.

With the control diet, the hen had no choice as to the time of day calcium was consumed. However, when given the simultaneous choice of diets providing energy, protein or calcium (E,P,Ca), the hen was able to select calcium at any time. Under these conditions, the hen consumed little or no calcium until the afternoon. This is the time of the day that the egg is usually in the shell gland, and the requirement for calcium should be higher at this time. When feeding limestone chips or oyster shell, it is recommended that the diet contain 1 to 1.5% calcium and that the remainder be supplied by the supplemental source. The ideal time to feed this calcium supplement would be in the afternoon, since this is when the hen normally has a high calcium requirement. Since separate feeding of calcium is not very practical, the only apparent solution is to have the calcium supplement mixed in the feed. The hen has the opportunity of leaving the oyster shell or limestone chips until the latter part of the day when it is required. This type of feeding method is being used by a number of producers with very good results. The feeding of limestone or oyster shell on a continuous free choice basis, or on top of a diet containing the full calcium requirement, is not recommended. It has been shown that egg shells with chalky deposits and rough ends are probably a direct result of feeding too much calcium to laying hens. Feeding birds oyster shell ad-libitum can also result in the production of soft shelled eggs. This unusual circumstance is due to a deficiency of phosphorus. If too much calcium is ingested, it must be excreted, usually as soluble calcium phosphate. This can lead to a deficiency of phosphorus, which results in no medullary bone being redeposited between successive periods of calcification.

Calcium is the nutrient most often considered when shell quality problems occur, although it is realized that deficiencies of vitamin $D_3$ and phosphorus can also result in weaker shells. Vitamin $D_3$ is required for normal calcium absorption, and so if inadequate levels are fed, induced calcium deficiency quickly occurs. Results from our laboratory suggest that diets devoid of synthetic vitamin $D_3$ are quickly diagnosed, because there is a dramatic loss in shell weight (Figure 9). The same situation is seen in Figure 10 when birds are fed deficient diets, and shell quality quickly deteriorates over two to three weeks. In this study, the basal diet was resupplemented with vitamin $D_3$ after four weeks, and there was rapid normalization of shell quality (Figure 10).

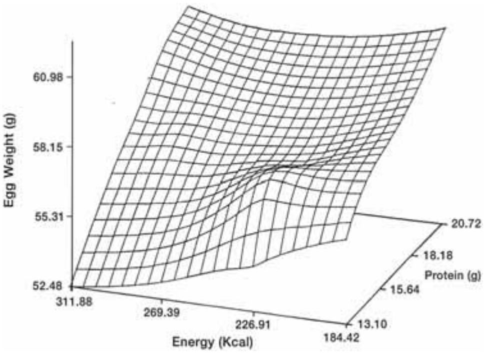
**Figure 9. Eggshell quality of layers fed various diets of vitamin D3.**



However, a more serious problem occurs with sub-optimal levels of vitamin $D_3$, where changes in shell quality are more subtle but nevertheless of economic significance (Figure 10).

A major problem with deficiency of vitamin $D_3$ is that this nutrient is very difficult to assay in complete feeds. If it is only at concentrations normally found in vitamin premixes that meaningful assays can be carried out, and so if $D_3$ problems are suspected, access to the vitamin premix is usually essential. In addition to uncomplicated deficiencies of $D_3$, problems can arise due to the effect of certain mycotoxins. Compounds such as zearalenone, that are produced by Fusarium molds, have been shown to effectively tie up vitamin $D_3$, resulting in poor egg shell quality. Under these circumstances, dosing birds with 300 IU $D_3$ per day for three consecutive days with water soluble $D_3$ may be advantageous.

**Figure 10. Egg weight (18-66 weeks) in response to intakes of energy and protein.**



Minimizing phosphorus levels is also advantageous in maintaining shell quality, especially under heat stress conditions. Because phosphorus is a very expensive nutrient, high inclusion levels are not usually encountered, yet limiting these within the range of 0.3 to 0.4%, depending upon flock conditions, seems ideal in terms of shell quality. Periodically, unaccountable reductions in shell quality occur and it is possible that some of these may be related to nutrition. As an example, vanadium contamination of phosphates causes an unusual shell structure, and certain weed seeds such as those of the lathyrus species, cause major disruptions of the shell gland.

Up to 10% reduction in eggshell thickness has been reported for layers fed saline drinking water, and a doubling in incidence of total shell defects seen with water containing 250 mg salt/litre. If a laying hen consumes 100g feed and 200 ml water per day, then water at 250 mg salt/litre provides only 50 mg salt compared to intake from the feed of around 400 mg salt. The salt intake from saline water therefore seems minimal in relation to total intake, but nevertheless shell quality problems often occur under these conditions. It appears that saline water results in limiting the supply of bicarbonate irons to the shell gland, and that this is mediated via reduced activity of carbonic anhydrase enzyme in the mucosa of the shell gland. However it is still unclear why saline water has this effect, in the presence of overwhelmingly more salt as provided by the feed. There seems to be no effective method of correcting this loss of shell quality in established flocks, although for new flocks, the adverse effect can be greatly reduced by adding 1 g vitamin C/litre drinking water.

**Table 10. Phase feeding of major nutrients after peak egg mass, assuming constant daily feed intake at 100g**

| Bird characteristics | | Diet levels (%) | | | |
|---|---|---|---|---|---|
| Age (wks) | Egg Production | Crude protein | Methionine | Calcium | Available phosphorous |
| <35 | 90 | 17.0 | 0.35 | 3.8 | 0.42 |
| 45 | 85 | 16.0 | 0.32 | 4.0 | 0.40 |
| 55 | 80 | 15.5 | 0.31 | 4.1 | 0.38 |
| 70 | 75 | 15.0 | 0.30 | 4.2 | 0.36 |
| 80 | 70 | 14.5 | 0.29 | 4.3 | 0.34 |

## Diet and Egg Size

Increasing the hen's intake of balanced protein will result in an increase in egg size while feeding higher levels of protein at the onset of production may help to increase egg size more rapidly. For strains of birds that produce many extra large eggs during the latter part of their egg production cycle, lowering the level of dietary protein during this period will result in slightly smaller and more uniform eggs.

In these situations, when considering changes to the level of dietary protein, the energy content of the diet must also be taken into account. If diets are suboptimal in energy, little increase in egg size will be noted by increasing the level of protein since the hen will utilize protein to meet requirements for energy. Indeed, one of the main factors limiting early egg size is that energy intake is suboptimal in many flocks that come into production at a young age and rise to peak production very rapidly. Where responses in egg size have been noted by adding tallow to laying diets, the rations (in most cases) have been low in energy and the increased energy has resulted in less protein being utilized for energy purposes. The effects of protein and energy on egg size are clearly demonstrated in Figure 11, which depicts the bird's response to a range of nutrient intakes. Unlike the situation with egg production (Figure 1), there is an obvious relationship between increased egg size and increased protein intake. At low protein intakes (less than 14-15 g/d), there is an indication of reduced egg size when energy intake is increased.

While it is fairly well established that levels of dietary crude protein and certain amino acids will influence egg size, it is not always clear if the responses recorded to crude protein per se can be totally attributed to intake of component amino acids. Table 11 shows a summary of six experiments reported by Waldroup where a range of methionine levels was tested at 0.2% cystine for various ages of bird. Table 11 indicates that as methionine level of the diet is increased, there is an almost linear increase in egg size. As the bird progresses through a production cycle, the egg weight response to methionine changes slightly. In the first period, between 25-32 weeks, using 0.38 vs 0.23% methionine results in a 5.6% increase in egg size. Comparable calculations for the other age periods show 7.3% improvement from 38 – 44 weeks, and 6.7% and 6.0% at 51-58 and 64-71 weeks respectively. The egg weight response to methionine therefore, closely follows the normal daily egg mass output of the laying hen. In another recent study, Jensen shows a generalized curvilinear response in egg weight to graded levels of methionine (Figure 11).

Over the last few years, there has been considerable research involving the source of methionine as it affects layer performance. When comparing DL-methionine with Alimet, Harms

**Figure 11. Egg weight response to methionine (Adapted from Calderon & Jensen, 1990).**

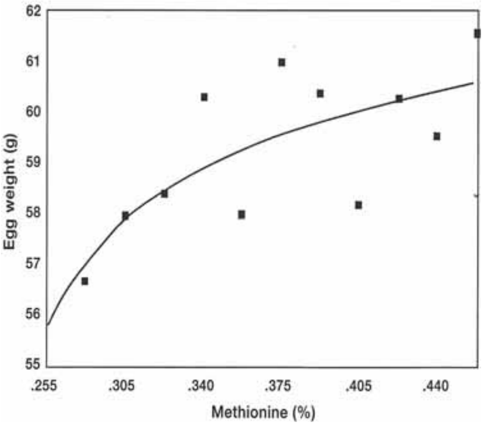


**Table 11. Effect of methionine on egg weight – mean of 6 experiments**

| | % iet Methionine[1] | | | | | |
|---|---|---|---|---|---|---|
| Bird age (wks) | 0.23 | 0.26 | 0.29 | 0.32 | 0.35 | 0.38 |
| 25-32 | 49.8 | 51.0 | 51.9 | 52.1 | 52.0 | 52.6 |
| 38-44 | 53.2 | 55.0 | 56.4 | 56.3 | 56.3 | 57.1 |
| 51-58 | 56.2 | 57.9 | 59.6 | 59.2 | 59.2 | 60.0 |
| 64-71 | 56.8 | 59.4 | 59.5 | 59.5 | 59.5 | 60.2 |

*1(@0.2% cys)*

*Adapted from Waidroup et al. (1995)*

shows the classical response of egg weight to both methionine sources (Table 12).

There has been a suggestion that L-methionine may in fact be superior to any other source. This product is not usually produced commercially because routine manufacture of methionine produces a mixture of D- and L-methionine. This is the only amino acid where there is apparently 100% efficacy of the D-isomer. However, most research data indicates no difference in potency of L- vs DL-methionine sources.

**Table 12. Effect of methionine source on layer performance**[1]

| Diet methionine (%) | Exp #1, Egg weight (g) | | Exp #2, Egg weight (g) | |
|---|---|---|---|---|
| | DL | Alimet | DL | Alimet |
| 0.228 | 54.5 | 54.5 | 51.5 | 51.5 |
| (basal) | 55.3 | 55.3 | 53.2 | 52.7 |
| 0.256 | 56.8 | 56.8 | 55.1 | 56.2 |
| 0.254 | 57.6 | 57.2 | 55.9 | 55.7 |
| 0.311 | 58.0 | 57.5 | 57.0 | 56.8 |
| 0.366-378 | | | | |

*[1] Mean 80% egg production*
*Harms and Russell 1994*

Attempts at reducing or tempering egg size later in the production cycle by phase feeding of protein or methionine have met with only limited success, likely due to the fact that producers are reluctant to use very low protein diets. Our studies indicate that protein levels around 13% and less are necessary to bring about a meaningful reduction in egg size (Table 13). However with protein levels much less than this, loss in egg numbers often occurs.

**Table 13. Effect of reducing dietary protein level on egg size of 60 week old layers (Av. 2, 28-day periods).**

| Dietary protein level (%) | Egg production (%) | Av. feed intake per day (g) | Egg wt. (g) | Daily egg mass (g) | Av. protein intake per day (g) |
|---|---|---|---|---|---|
| 17 | 78.8 | 114 | 64.8 | 51.0 | 19.4 |
| 15 | 77.5 | 109 | 64.3 | 49.7 | 16.4 |
| 13 | 78.3 | 107 | 62.2 | 49.1 | 13.9 |
| 11 | 72.7 | 108 | 61.7 | 45.1 | 11.9 |
| 9 | 54.3 | 99 | 58.2 | 36.1 | 8.9 |

*All diets 2800 kcal ME/kg*

Methionine levels can also be adjusted in an attempt to control late cycle egg size. Results of Peterson show the tempering of egg size with reduced methionine levels (Table 14). However, these results are often difficult to achieve under commercial conditions because reduction in diet methionine levels often leads to loss in egg numbers and body weight. Phase feeding of amino acids must, therefore, be monitored very closely. As stated at the outset of this section, mature body weight is the main determinant of egg size, and this applies particularly to late-cycle performance.

The best way to control late cycle egg size is through manipulation of body-weight at time of light stimulation. Larger birds at maturity will produce much larger late cycle eggs and vice versa. There is an obvious balance necessary between trying to reduce late cycle egg size without unduly reducing early cycle egg size. Waldroup recently outlined estimates of methionine and methionine + cystine requirements for both egg production and for egg weight/mass (Table 15).

**Table 14. Methionine and late cycle egg size (g)**

| Daily methionine intake (mg/day) | Exp. 1 38-62 weeks | Exp. 2 38-70 weeks | Exp. 3 78-102 weeks |
|---|---|---|---|
| 300 | 60.1a | 63.7a | 66.3a |
| 285 | 60.3a | 63.1b | 65.5b |
| 270 | 59.1ab | 62.0c | 64.0c |
| 255 | 58.5b | 62.0c | 63.9c |
| Average egg prod (%) | 86 | 80 | 75 |

*Adapted from Peterson et al. (1983)*

**Table 15. Estimated methionine and methionine + cystine requirements (mg/day)**

| | Bird age (wks) | Egg # | Egg weight | Egg mass |
|---|---|---|---|---|
| Methionine | 25-32 | $364^b$ | $356^b$ | $369^b$ |
| | 38-48 | $362^b$ | $380^a$ | $373^b$ |
| | 51-58 | $384^a$ | $364^a$ | $402^a$ |
| | 64-71 | $374^{ab}$ | $357^b$ | $378^b$ |
| Methionine + cystine | 25-32 | $608^b$ | $610^{ab}$ | $617^b$ |
| | 38-45 | $619^b$ | $636^a$ | $627^b$ |
| | 51-58 | $680^a$ | $621^{ab}$ | $691^a$ |
| | 64-71 | $690^a$ | $601^b$ | $676^a$ |

*Adapted from Waldroup et al. (1995)*

During peak egg mass output (38-45 weeks), the methionine requirement for egg size is greater than for egg numbers, while the latter requirement peaks at 51-58 weeks of age. If these data are verified in subsequent studies, it suggests that we should be very careful at reducing methionine levels much before 60 weeks of age.

It is well known that linoleic acid also affects egg size. Although there is some controversy as to the level required for maximum egg size, it would appear that a level of 1% in the diet should be adequate. Results from a trial aimed at increasing early egg size with high levels of linoleic acid are shown in Table 16. In this study, linoleic acid had no effect on egg size. It should be pointed out that this particular flock matured early and peaked very rapidly. It might well be that the pullets were producing maximum egg mass with respect to body size and thus could not use additional nutrients to advantage.

**Table 16. Influence of linoleic acid intake on early egg size (average performance, 18-34 weeks)**

| Treatments | Edproduction (%) | Egg wt. (g) | Feed (g/d) | Linoleic acid intake (md/day) |
|---|---|---|---|---|
| Carbohydrate | 64.3 | 49.1 | 86.8 | 105$^{c}$ |
| 10% Tallow | 57.5 | 49.5 | 82.5 | 305$^{b}$ |
| 10% Corn oil | 60.1 | 49.9 | 88.6 | 4607$^{a}$ |

*All diets contained 15% protein*

$^{a-c}$ *means followed by different letters are significantly different*

## "Pickouts and Blowouts"

In the past, pickout or blowout losses of 2 to 3% per month over several months after housing pullets were not uncommon. Such losses were usually the result of a number of factors working together rather than any single problem. In most cases, the problem was due to picking rather than any physical stress resulting in "blowouts". Some of the problems that can lead to pickouts or blowouts are as follows:

- lights too bright (or sunlight streaming into buildings)
- pen temperature too high (poor ventilation)
- improper beak trimming
- pullets carrying an excess of body fat
- poor feathering at time of housing
- too early a light stimulation
- too high protein/amino acid in the diet causing early large egg size relation to body and frame size

The condition is usually accentuated in multiple bird cages and is a factor of floor space per bird rather than bird density. Frequently, the incidence of picking has been shown to be higher in multiple bird cages where there is in excess of 460 sq cm of space per bird. When birds are more crowded, they do not seem to be as aggressive. One of the most effective ways of avoiding a problem is to keep the light intensity low. Where rheostats are available, these should be adjusted to a sufficiently low level that picking or cannibalism is kept to a minimum. With early maturing pullets, or pullets that reach peak production two to three weeks earlier than was commonly found a few years ago, a mortality picture similar to those outlined above, is seldom encountered. However, what many producers are encountering is a pickout problem that starts around peak production and, although not high, (less than 0.5% per month) often remains with the flock throughout the entire laying period. While this type of problem is aggravated by bright lights, as well as crowding and poor beak trimming, it is felt that one of the main factors triggering the condition is low body weight. Even if pullets mature at body weights recommended by the breeder, many of them are up to 100g lighter than standard at peak production. This, we suspect, is due to the fact that the pullet is coming into production with a minimum of body reserves; it also has a low feed consumption as it has been conditioned on a feed intake near to maintenance just prior to commencement of lay and thus has not been encouraged to develop a large appetite. The pullet is laying at a rapid rate and thus utilizes her body reserves (fat) in order to maintain egg mass production. This smaller body weight bird is often more nervous and so more prone to picking. Under these conditions, the nutritional management program of pullets outlined earlier in this chapter should be followed.

Prolapse can sometimes be made worse by feeding high protein/amino acid diets to small weight pullets in an attempt to increase early egg size. Coupled with an aggressive step up lighting program, this often leads to more double yolk eggs and so greater incidence of prolapse and blowouts. Such pullets are often below standard weight at 12-14 weeks, and so any catch-up growth is largely as fat, which also accentuates the problem. Being underweight at 12-14 weeks usually means that they have reduced shank length, and because the long bones stop growing at this time, short shanks are often used as a diagnostic tool with prolapse problems in 22-24 weeks old pullets.

## Fatty Liver Syndrome

The condition of fatty liver in poultry has been observed for quite some time. While it is true that an alteration in liver function can lead to a build-up of fat in the liver, many cases of fatty liver in laying hens can be traced to an imbalance in nutrient intake. Low protein, high energy diets and those in which there is an amino acid imbalance or deficiency can be major contributors to a fatty liver condition in layers. It is known that diets low in lipotrophic factors such as choline, methionine and vitamin B12 can result in fatty infiltration of the liver.

However, these nutrients are seldom directly involved in most of the fatty liver problems reported from the field. Excessive feed intake (more specifically energy intake) is also a major cause of the condition. It is well known that laying hens will overconsume energy, especially with high energy diets and this is particularly true of high producing hens. Pullets reared on a feeding program that tends to develop a large appetite or encourages “over-eating” (high fiber diets or skip-a-day feeding), are often more susceptible to the condition when offered a high energy diet on a free choice basis during lay. There is some information to suggest that daily fluctuations in temperature, perhaps affected by the season of the year, will stimulate hens to over-consume feed. Hence, it is important to attempt some type of feed restriction program if feed intake appears to be excessive.

When fatty liver is a problem, adding a mixture of so-called “lipotrophic factors” to the diet is often recommended. A typical addition may involve 60 mg $CuSO_4$, 500 mg choline, 3 $\mu$g vitamin B12 and 500 mg methionine per kg of diet. It should be emphasized that in many cases, the addition of these nutrients will not cure the problem. Increasing the level of dietary protein by 1 to 2% seems to be one of the most effective ways of alleviating the condition. However, such treatments do not work in all cases. Another treatment that may prove effective is to increase the supplemental fat content of the diet. This apparently contradictory move is designed to offer the birds a greater proportion of energy as fat rather than carbohydrate. The idea behind this diet manipulation is that by reducing carbohydrate load there is less stress on the liver to synthesize new fat required for egg yolk production. By supplying more fat in the diet, the liver merely has to rearrange the fatty acid profile within fats, rather than synthesize new fat directly. For this treatment to be effective, the energy level of the diet should not be changed, the recommendation merely being substitution of carbohydrate with fat. This concept may be the reasoning for apparent effectiveness of some other treatments for fatty liver syndrome. For example, substitution of barley or wheat for corn has been suggested, and this usually entails greater use of supplemental fat with these lower energy ingredients. Similarly, substitution of soybean meal with canola or sunflower meals usually means using more supplemental fat if energy level of the diet is to be maintained.

More recent evidence suggests that mortality is caused by eventual hemorrhaging of the liver, and that this is accentuated or caused by oxidative rancidity of the accumulated fat. On this basis, we have seen a response to adding various antioxidants, such as ethoxyquin and vitamin E. Adding ethoxyquin at 150 mg/kg diet and extra vitamin E up to 50-60 IU/kg has been shown to reduce the incidence of hemorrhage mortality.

Experience has shown that it is difficult to increase production in a flock once the condition is established. Thus it is important that a proper program be followed to prevent the development of fatty livers. In some cases, the cause of the trouble can be traced back to pullets coming into the laying house carrying an excess of body fat. If these birds are then subjected to a laying diet in which the balance of protein and energy is slightly suboptimal for a particular strain of bird, a build-up of fat in the liver may occur. Also, the feeding of crumbles or pellets in the laying house may aggravate this condition, since the hen may overeat such rations if offered on a free choice basis.

Recent information suggests that a condition similar to the so-called fatty liver syndrome may be caused by certain types of molds or mold toxins. Although no definite relationship has been established to date between molds and fatty livers, care should be taken to ensure that molds are not a factor contributing to poor flock performance. From time to time, canola meal has been implicated with the fatty liver syndrome. While it is true that there were earlier reports with some of the high glucosinolate rapeseed meals triggering such a condition, there is no evidence to suggest that the new canola varieties are a factor in the fatty liver condition. Hemorrhage due to rapeseed is usually not associated with excess fat infiltration of the liver.

## Molting Programs

Molting programs are designed to prolong the productive life of layers. It is commonly practised for egg type layers and turkey breeders, and is also being tried with broiler breeders in some areas. The aim of a molting program is not necessarily to induce a feather molt, but rather to shut down the reproductive system for a period of time. When birds resume laying, egg shell quality is improved, although egg size will also be increased. A number of molting programs have been used over the years involving feed withdrawal, diets low in sodium or calcium, or diets with high levels of zinc.

Feed/water withdrawal usually involves a prolonged molt period, whereas low sodium and calcium and high zinc diets have been tried as a means of inducing a short “pause” in lay, rather than a distinct molt. In general, these “pause” methods have not proven as reliable as the classical feed/water withdrawal. It is difficult to quantitate the economic advantage of a molting program. For example, if egg prices are high, then a short molt program may be beneficial, whereas with low egg prices, especially for large and extra large grades, there is no advantage to a very quick return to production. The criteria used in developing a molting program should be body weight and mortality. Mortality should not increase substantially during a molt and should not exceed 0.2% per day. If mortality is higher, then the duration and/ or degree of feed restriction should be reconsidered.

Perhaps the most important criterion is body weight. Ideally birds start their second laying cycle at the same weight as when they were juvenile pullets. This means that the degree of feed restriction must be sufficient to cause weight loss equivalent to that gained by the bird during the first cycle. In practice, this is often very difficult. For example, a flock of birds entering their first cycle at 1.3 kg may well be 1.4 kg entering their second cycle. In large part, this is the reason for increased egg size with second cycle birds. Weight loss should therefore be in proportion to bird weight gain during the first cycle. For flocks that are very heavy, more severe restriction is required, and vice versa. The time of initiation of a forced molt is also quite variable. In California, where most of the molting work has been pioneered by Dr. Don Bell, it is quite common to have two or three relatively short laying cycles - in this situation the first molt period may start at 60-65 weeks of age. More commonly, a molt will be initiated when layers are 75-80 weeks of age, when egg shell quality is a problem.

The main advantage of a molting program, is improved shell quality during the second and third laying cycles. The longer the molt period, within reason, the better the persistency of egg production and shell quality during a second or third cycle. For many situations therefore, the old saying of “short molt, short second cycle” holds true.

## Cage Layer Fatigue

As its name implies, cage layer fatigue (CLF) is a syndrome most commonly associated with laying hens held in cages, and so its first description in the mid 1950’s coincides with commercial acceptance of this housing system. Apart from the cage environment, CLF also seems to need a high egg output to trigger the condition, and for this reason, it has traditionally been most obvious in White Leghorns. At around the time of peak egg output, birds become lame, and are reluctant to stand in the cage. Because of the competitive nature of the cage environment, affected birds usually move to the back area of the cage, and death can occur due to dehydration/starvation because of their reluctance to drink or eat. The condition is rarely seen in litter floor managed birds and this leads to the assumption that exercise may be a factor. In fact, removing CLF birds from the cage during the early stage of lameness and placing them on the floor, usually results in a complete recovery. However, this practice is usually not possible in large commercial operations. In the 1960-70’s up to 10% mortality was common, although now the incidence is considered problematic if 0.5% of the flock are affected. There is no good evidence to suggest an association of CLF to general bone breakage in layers, although the two conditions are often described as part of the same general syndrome.

If birds are identified early, they seem alert and are still producing eggs. The bones seem fragile, and there may be broken bones. Dead birds may be dehydrated or emaciated, simply due to the failure of these birds to eat or drink. The ribs may show some beading although the most obvious abnormality is a reduction in the density of the medullary bone trabeculae. Paralysis is often due to fractures of the fourth and fifth thoracic vertebrae causing compression and degeneration of the spinal cord. If birds are examined immediately after the paralysis is first observed, then there is invariably a partly shelled egg in the oviduct, and the ovary contains a rich hierarchy of yolks. If birds are examined some time after the onset of paralysis, then the ovary is often regressed, due to reduced nutrient intake.

CLF is obviously due to an inadequate supply of calcium available for shell calcification, and the bird's plundering of unconventional areas of its skeleton for such calcium. Because calcium metabolism is affected by the availability of other nutrients, the status of phosphorus and vitamin $D_3$ in the diet and their availability are also critical. Birds fed diets deficient in calcium, phosphorus, or vitamin $D_3$ will show cage layer fatigue assuming there is a high egg output.

Calcium level in the pre-lay period is often considered critical in preventative measures for CLF. Feeding low calcium (1%) grower diets for too long a period, or even 2% calcium pre-lay diets up to 5% egg production often leads to greater incidence of abnormal bone development. It has been suggested that the reappearance of CLF in some commercial flocks may be a result of too early a sexual maturity due to the genetic selection for this trait coupled with early light stimulation. Feeding a layer diet containing 3.5% Ca vs a grower diet at 1% Ca, as early as 14 wk of age, has proven beneficial in terms of an increase in the ash and calcium content of the tibiotarsus (Table 17).

**Table 17. Diet calcium and bone characteristics of young layers in response to prelay diet calcium.**

| Time of change to 3.5% Ca | Tibiotarsus Ash (%) | Tibiotarsus Ca (mg/g) |
|---|---|---|
| 20 weeks | 53.5c | 182b |
| 18 weeks | 55.7b | 187b |
| 17 weeks | 59.3a | 202a |
| 16 weeks | 58.9a | 199a |
| 15 weeks | 58.4a | 197a |
| 14 weeks | 57.9a | 196a |

*Adapted from Keshavarz (1989)*

Feeding a high calcium diet far in advance of maturity seems unnecessary, and in fact, may be detrimental in terms of kidney urolithiasis. Changing from a low to a high calcium diet should coincide with the observation of secondary sexual characteristics, and especially comb development which usually precedes first oviposition by 14-16 days.

There have been surprisingly few reports on the effect of vitamin $D_3$ on CLF in young birds. It is assumed that D3 deficiency will impair calcium utilization, although there are no reports of testing graded levels of this nutrient as a possible preventative treatment. The other major nutrient concerned with skeletal integrity is phosphorus, and as expected, phosphorus deficiency can accentuate effects of CLF. While phosphorus is not directly required for shell formation, it is essential for the replenishment of Ca, as CaPO4, in medullary bone during successive periods of active bone calcification. Without adequate phosphorus in the diet, there is a failure to replenish the medullary Ca reserves, and this situation can accelerate or precipitate the onset of CLF and other skeletal problems. Low phosphorus intake is sometimes caused by the trend towards lower levels of diet phosphorus coupled with very low feed intake of pullets through early egg production.

## Bone Breakage In Older Hens

CLF may relate to bone breakage in older hens, although a definitive relationship has never been verified. It is suspected that like the situation of CLF with young birds, bone breakage in older birds results as a consequence of impaired calcification of the skeleton over time, again related to a high egg output coupled with the restricted activity within the cage environment. Few live birds have broken bones in the cage, the major problem occurring when these birds are removed from their cages and transported to processing units. Apart from the obvious welfare implications, broken bones prove problematic during the mechanical deboning of the muscles.

Adding more calcium to the diet of older layers does not seem to improve bone strength, and in certain situations can lead to excessive eggshell pimpling. Adding both calcium and phosphorus to the diet has given beneficial results in some instances, although results are quite variable. In young birds at least, adding 300 ppm flourine to the water has improved bone strength, although there are no reports of such treatment with end of lay birds. Moving birds from a cage to litter floor environment seems to be the only treatment that consistently improves bone strength. This factor indicates that exercise per se is an important factor in bone strength of caged birds, but does not really provide a practical solution to the problem at this time.

It is not currently known how to improve the bone integrity of older high producing hens, without adversely affecting other traits of economic significance. For example, it has been shown that bone breaking strength in older birds can be increased by feeding high levels of vitamin D3. Unfortunately, this treatment also results in an excessive pimpling of the eggshells (as occurs with extra calcium) and these extra calcium deposits on the shell surface readily break off causing a leakage of the egg contents. It may be possible to improve the skeletal integrity of older birds by causing cessation of ovulation for some time prior to slaughter. Presumably, the associated reduction in the drain of body calcium reserves would allow re-establishment of the integrity of the susceptible medullary bones. Currently, such a feeding strategy is uneconomical, although consideration for bird welfare may provide the impetus for research in this area.

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# Feeding Programs For Egg-strain Pullets Up To Maturity

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## Introduction

The major concern today with feeding and managing laying hens, is achieving desired weight-for-age in the pullet, and especially during the early growth period. Genetic selection has been for reduced body weight in these birds, in order to improve feed efficiency, but a consequence of this is reduced feed intake. Ensuring that birds consume sufficient nutrients daily is made even more difficult when ingredient quality is poor and birds are subjected to heat stress or disease situations. The pullet manager must be skilful in managing diets and the environment, such that pullets consume an adequate level of nutrients up to maturity. While such nutrient intake varies with strain and environment, goals are around 800g crude protein and 18 Mcal ME consumed up to 18 weeks of age.

Diet specifications for pullets are shown in Table 1.

**Table 1. Diet specifications for growing Leghorn pullets.**

| | Chick starter | | Chick grower | | Pre-lay |
|---|---|---|---|---|---|
| Approximate protein level (%) | 18.0 | 20.0 | 15.0 | 17.0 | 17.0 |
| **Amino acids (% of diet)** | | | | | |
| Arginine | 0.94 | 1.03 | 0.78 | 0.92 | 0.80 |
| Lysine | 0.90 | 1.00 | 0.72 | 0.85 | 0.70 |
| Methionine | 0.41 | 0.45 | 0.34 | 0.39 | 0.35 |
| Methinonine + cystine | 0.66 | 0.72 | 0.55 | 0.65 | 0.60 |
| Tryptophan | 0.18 | 0.19 | 0.16 | 0.18 | 0.17 |
| Histidine | 0.33 | 0.36 | 0.28 | 0.32 | 0.30 |
| Leucine | 1.16 | 1.28 | 0.95 | 1.10 | 1.00 |
| Isoleucine | 0.62 | 0.68 | 0.51 | 0.61 | 0.55 |
| Phenylalanine | 0.58 | 0.64 | 0.48 | 0.57 | 0.51 |
| Phenylalanine + tyrosine | 1.13 | 1.24 | 0.93 | 1.11 | 1.00 |
| Threonine | 0.56 | 0.62 | 0.47 | 0.55 | 0.50 |
| Valine | 0.69 | 0.76 | 0.67 | 0.68 | 0.67 |
| Metabolizable energy (kcal/kg) | 2850 | 2900 | 2850 | 2950 | 2850 |
| Calcium (%) | 1.0 | 1.0 | 0.85 | 0.90 | 2.0 |
| Available phosphorus (%) | 0.40 | 0.42 | 0.37 | 0.39 | 0.43 |
| Sodium (%) | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| **Vitamins (per kg of diet)** | | | | | |
| Vitamin A (I.U.) | 9000 | | | 7000 | |
| Vitamin D3 (I.U.) | 2500 | | | 2000 | |
| Choline equivalents (mg) | 1200 | | | 1000 | |
| Riboflavin (mg) | 5.0 | | | 4.0 | |
| Pantothenic acid (mg) | 13.0 | | | 11.0 | |
| Vitamin B12 (mg) | 0.012 | | | 0.010 | |
| Folic acid (mg) | 0.75 | | | 0.60 | |
| Biotin (mg) | 0.20 | | | 0.15 | |
| Niacin (mg) | 50.0 | | | 40.0 | |
| Vitamin K (mg) | 2.0 | | | 2.0 | |
| Vitamin E (I.U.) | 30.0 | | | 20.0 | |
| Thiamin (mg) | 2.2 | | | 2.0 | |
| Pyridoxine (mg) | 4.0 | | | 3.5 | |
| **Trace minerals (per kg of diet)** | | | | | |
| Managanese (mg) | 70 | | | 70 | |
| Iron (mg) | 80 | | | 80 | |
| Copper (mg) | 8.0 | | | 8.0 | |
| Zine (mg) | 60.0 | | | 60.0 | |
| Selenium (mg) | 0.3 | | | 0.2 | |
| Iodine (mg) | 0.4 | | | 0.4 | |

## Feeding Management Of Growing Pullets

### A. General Considerations

It is generally agreed that most Leghorn and brown egg strains have changed over the last five to 10 years, and because of this, nutritional management is becoming more critical. In essence, these changes relate to age at maturity, although it is questionable that this has changed suddenly in just a few years. In fact, what has been happening is that age of maturity has slowly been decreasing by about one day per year. Unfortunately, many producers are just now becoming aware of earlier maturity because their conventional programs are no longer working, and this is especially true for many strains of brown egg pullets. Moving birds to laying cages at 21-22 weeks is no longer feasible, and this now invariably results in management problems. Similarly, first egg appearing at 16-18 weeks means that we must critically review our rearing programs. The key to successful nutritional management today is through maximizing body weight of the pullet. Pullets that are on target or slightly above target weight at maturity will inevitably be the best producing birds for the shell-egg market.

The traditional concern with early maturity has been that it results in small egg size. Results from our early studies indicate the somewhat classical effect of early maturity in Leghorns without regard to body weight (Table 2).

Table 2. Pullet maturity and egg characteristics

| Age at housing | Egg Production (%) | | Egg size (% large) | |
|---|---|---|---|---|
| | 18-20 weeks | Mean to 35 weeks | 30 weeks | 63 weeks |
| 15 weeks | 32.0 | 92 | 17 | 44 |
| 18 weeks | 12.0 | 92 | 21 | 65 |
| 21 weeks | 0 | 91 | 37 | 69 |

Table 3. Effect of body weight on egg size

| 18 weeks weight (g) | Early egg weight |
|---|---|
| 1100 | 46.9$^a$ |
| 1200 | 48.4$^b$ |
| 1280 | 8.8b$^c$ |
| 1380 | 49.7$^c$ |

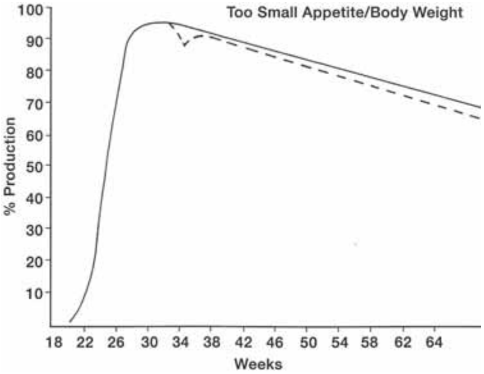
$^{a\text{-}c}$ *means followed by different letters are significantly different*

There seems little doubt that body weight and/or body composition are the major factors influencing egg size both at maturity and throughout the remainder of the laying period. Summers and Leeson (1983) concluded that body weight is the main factor controlling early egg size (Table 3).

We concluded that although there is evidence to indicate that nutrients such as protein, methionine and linoleic acid can influence egg size throughout the laying cycle, these nutrients have little effect on early egg size. This is probably related to the pullet producing at maximum capacity at least up to the time of peak egg mass.

Although it is fairly well established that body weight is an important criterion for adequate early production, there is still insufficient evidence regarding optimum body structure and composition. Frame size is being discussed, and is now most frequently included in breeder management guides as a form of monitoring. It is known that most (90%) of the frame size is developed early, and so by 12-16 weeks of age, the so-called "size" of the pullet is fixed. While this parameter is useful as another monitoring tool and its measurement should be encouraged, we have had little success in affecting frame size without also affecting body weight. It therefore seems very difficult to produce, by nutritional modification, pullets that are below target weight yet above average frame size and vice versa. The relationship between body weight and shank size is further complicated by the fact that environmental temperature also affects bone length independent of nutrition.

Figure 1. Reduction in egg production after peak, associated with small appetite and body weight.



It would appear that early maturing chickens reach sexual maturity at significantly younger ages, but at similar body weights compared to later maturing birds. It seems as though early maturing birds achieve a threshold level of body mass and commence production when the minimum physiological age is reached, while late maturing birds at the same age do not have the body mass required for production. Recent reports have indicated the requirement of a certain lean body mass prior to onset of maturity. With most mammals, attainment of minimum fat reserves are essential for puberty, and so it seems likely that body composition is as important as total body mass in influencing the onset of egg production. In studies involving a relatively small number of birds, we have seen no correlation between age at first egg and either percentage or absolute levels of body fat. While no clear picture has yet emerged with respect to body composition and maturity, it seems likely that birds having some energy reserve as they approach peak egg production are less prone to subsequent problems. Too frequently, a production curve as shown in Figure 1 is observed with commercial flocks.

Our experience suggests that if this type of production loss is not due to an identifiable disease and/or management problem, then it most likely relates to birds being deficient in energy. It is perhaps not too surprising that birds are in such a precarious situation with respect to energy balance. Most mammals such as cows and sows must lose body weight during peak lactation in order to meet energy requirements. Perhaps the most classical case of energy deficiency at this time is seen with the turkey breeder. Due to a decline in feed intake from time of first lighting through to peak egg production, the turkey breeder necessarily loses considerable body mass in an attempt to maintain energy balance. It is likely that the same situation applies to both the Leghorn and modern brown egg type pullet. Obviously, the effect is most pronounced for underweight flocks with small appetites where energy intake is minimal. In fact, with many flocks exhibiting production characteristics as shown in Figure 1, it is body weight at housing that deserves immediate investigation rather than factors occurring later at the time of the production loss.

The key to solving many of our present industry problems would therefore seem to be attainment of "heavy" pullets at desired age of maturity. In this instance, "heavy" refers to the weight and condition which will allow the bird to progress through maturity with optimum energy balance. It is likely that such conditions will be a factor of the flock in question, being influenced by stocking density, environmental temperature, feather cover, etc. Unfortunately, attainment of desired weight for age has not always proven easy, especially where earlier maturity is desired or when adverse environmental conditions prevail. Leeson and Summers (1981) suggested that energy intake of the pullet is the limiting factor to growth rate, since regardless of diet specifications; pullets seem to consume similar quantities of energy (Table 4).

All of these birds were of comparable weight even though diet specifications were dramatically variable. As seen in Table 4, birds consumed similar quantities of energy, even though protein intake varied by 85%. These data suggest that if adequate protein intake is achieved, additional diet protein does little to stimulate growth rate.

In more recent studies, we have reared Leghorn pullets on diets varying in protein or energy, and again, energy intake seems to be the major factor influencing body weight (Tables 5 and 6).

**Table 4. Energy intake of growing pullets (8-15 weeks)**

| Diet energy-protein | 15 weeks body wt (g) | Energy intake (Mcal) | Rotein intake (g) |
|---|---|---|---|
| 1. 2950 kcal – 14% CP | 1272 | 9.77 | 464$^{c}$ |
| 2. 3100 kcal – 24% CP | 1267 | 9.17 | 718$^{a}$ |
| 3. 3200 kcal – 20% CP | 1291 | 9.51 | 597$^{b}$ |

$^{a\text{-}c}$ *means followed by different letters are significantly different*

**Table 5. Effect of diet protein level (0.20 weeks) on pullet growth and nutrient intake**

| Diet protein | Body wt 20 weeks (g) | Energy intake 0.20 weeks (Mcal) | Protein intake 0-20 weeks (kg) |
|---|---|---|---|
| 15 | 1445 | 24.3 | 1.28$^{d}$ |
| 16 | 1459 | 22.9 | 1.28$^{d}$ |
| 17 | 1423 | 22.9 | 1.37$^{cd}$ |
| 18 | 1427 | 22.0 | 1.39$^{c}$ |
| 19 | 1444 | 22.9 | 1.53$^{b}$ |
| 20 | 1480 | 23.0 | 1.62$^{a}$ |

**Table 6. Effect of diet energy level (0-20 weeks) on pullet growth and nutrient intake**

| Diet energy (kcal ME/kg) | Body wt 20 weeks (g) | Energy intake 0.20 weeks (Mcal) | Protein intake 0-20 weeks (kg) |
|---|---|---|---|
| 2650 | 132$^{bc}$ | 20.6$^{c}$ | 1.40$^{a}$ |
| 2750 | 1378$^{bc}$ | 21.0$^{bc}$ | 1.37$^{a}$ |
| 2850 | 1422$^{ab}$ | 21.8$^{ab}$ | 1.37$^{a}$ |
| 2950 | 1489$^{a}$ | 22.1$^{ab}$ | 1.35$^{ab}$ |
| 3050 | 1468$^{a}$ | 21.4$^{abc}$ | 1.26$^{c}$ |
| 3150 | 1468$^{a}$ | 22.5$^{a}$ | 1.29$^{bc}$ |

*(All diets 18% CP)*

$^{a\text{-}c}$ *means followed by different letters are significantly different*

These studies indicate the growth rate is more highly correlated with energy intake than with protein intake. This does not mean to say that protein (amino acid) intake is not important to the growing pullet. Protein intake is very important, but there does not seem to be any measurable return from feeding more than 800g of protein to the pullet through 18 weeks of age. On the other hand, it seems as though the more energy consumed by the pullet, the larger the body weight at maturity. Obviously, there must be a fine line between maximizing energy intake and creating an obese pullet.

## *B. Maximizing Nutrient Intake*

If one calculates expected energy output in terms of egg mass and increase in body weight, and relates this to feed intake, then it becomes readily apparent that the Leghorn must consume at least 90g/bird/day and the brown egg bird close to 100g/bird/day at peak production. With egg-type stock, feeding is related to appetite and so our management programs must be geared to stimulating appetite. The practical long-term solution is to rear birds with optimum body weight and body reserves as they begin production. This situation has been aggravated in recent years, with the industry trend of attempting to rear pullets on minimal quantities of feed. Unfortunately, this move has coincided with genetically smaller body weights and hence smaller appetites, together with earlier sexual maturity.

In order to maximize nutrient intake, one must consider relatively high nutrient dense diets, although these alone do not always ensure optimum growth. Relatively high protein (16-18% CP) with adequate methionine (2% CP) and lysine (5% CP) levels together with high energy levels (2800-3000 kcal/kg) are usually given to Leghorn pullets, especially in hot weather situations. However, there is some

**Table 7. Influence of diet energy on growth and nutrient intake of Leghorn pullets maintained at 30 or 18°C to 18 weeks of age**

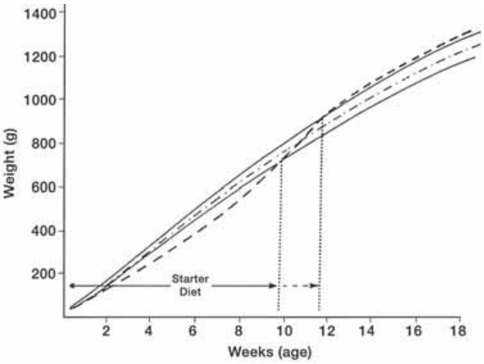
| | Body wt 126d (g) | Total feed intake (kg) | ME intake (Mcal) | Protein intake (g) |
|---|---|---|---|---|
| **Temperature 18°C** | | | | |
| 1. 2500 kcal ME/kg | 1398 | 7.99 | 20.04 | 1330 |
| 2. 3000 kcal ME/kg | 1434 | 6.98 | 21.07 | 1160 |
| **Temperature 30°C** | | | | |
| 1. 2500 kcal ME/kg | 1266 | 6.05 | 15.17 | 1010 |
| 2. 3000 kcal ME/kg | 1218 | 5.19 | 15.69 | 870 |

evidence to suggest that high energy diets are not always helpful under such warm conditions. This situation may relate to stimulation of nutrient intake when lower energy diets are fed at high temperatures (Table 7). In this recent study, Leghorn pullets were heavier at 126 days when fed the high energy diet in the cool environment, but diet had no effect at 30°C. As expected, pullets ate less of the high energy diet, and because all other nutrient levels were fixed, this results in reduced intake of all nutrients except energy. Pullets therefore ate less protein and amino acids when fed 3000 vs 2500 kcal ME/kg, and this can be critical where intake per se is less at 30°C. The pullets fed 3000 kcal/kg are borderline in intake of balanced protein at 870g versus our requirement for 800 g to this age. High energy diets may therefore not always be beneficial under heat stress conditions, and intake of other nutrients such as protein and amino acids must be given priority during formulation.

The Leghorn pullet eats for energy requirement, albeit with some imprecision, and so energy:protein balance is critical. All too often, we see inadequate amino acid intake when high energy corn-based diets are used, the result of which is pullets that are both small and fat at maturity.

One of the most important concepts today in pullet feeding, is to offer diets according to body weight and condition of the flock, rather than according to age. For example, traditional systems involve feeding starter diets for about six weeks followed by grower and then perhaps developer diets. This approach does not take into account individual flock variation, and today this can be most damaging to underweight flocks. It is becoming more difficult to attain early weight for age. This means that flocks are often underweight at four to six weeks of age. This can be for a variety of reasons such as sub-optimal nutrition, heat stress, disease, etc. The worse thing that can happen to these flocks is an arbitrary introduction of a grower diet, merely because the flock has reached some set age. Today, we must feed the higher nutrient dense starter until the target weight is reached. For example, Figure 2 shows an underweight flock at six weeks.

**Figure 2. Pullet growth in relation to feeding program.**



To change this flock to a grower at six weeks of age will cause problems because the flock will likely stay small until maturity, then be late maturing and produce a sub-optimal number of eggs that will also be small. This type of flock can most effectively be "corrected" by prolonged feeding of the starter diet. In this situation, the birds reach the low end of the guide weight at almost 10 weeks of age (Fig. 2). At this time, a grower diet could be introduced. Since the flock is showing a growth spurt, then feeding to almost 12 weeks could be economical – we now have a flock that is "heavy". We have therefore converted the flock from being underweight and a potential problem, to one that is slightly over weight and so ideally suited to realizing maximum genetic potential during peak production. Some producers, and especially contract pullet growers, are sometimes reluctant to accept this type of program, since they correctly argue that feeding a high protein diet for 10-12 weeks will be more expensive. Depending upon local economic conditions, feeding an 18% protein starter diet for 12 versus six weeks of age, will cost the equivalent of two eggs. A bird in ideal condition at maturity will produce far in excess of these two eggs relative to a small underweight bird at maturity.

## *C. Suggested Feeding Program*

The following schedule is recommended for growing pullets to maturity:

Starter 18-19%CP; 2750-2900 kcal ME/kg
Day old _____________Target body weight

Grower 15-16%CP; 2750-2900 kcal ME/kg
Target wt ____________Mature body size

Pre-lay or layer 16-18%CP; 2750-2900 kcal ME/kg
Mature body size __________1st egg

As previously indicated, we are not making recommendations regarding age or even dictating the body weight at which diet changes should occur. Rather, the recommendations dictate the need for flexibility and the treatment of each flock as an individual case. For example, the starter diet is to be used until target weight for age is achieved. Hopefully, this will be at around 450g when the Leghorn bird is six to eight weeks of age. However, each flock will be subjected to varying environmental conditions, and so this may vary. The time of change to a lower-nutrient dense diet is when a desired weight-for-age is achieved, which we suggest is a weight that will be towards the top side of the breeder's growth curve. Changing at a specific weight, or a specific age in isolation can lead to disastrously underweight flocks.

In our recommendations, we suggest the lower-nutrient dense grower diets to be fed from this target weight-for-age up until the desired mature body size is achieved. Again, we are not dictating a specific mature body weight, since this may be varied at the desire of the pullet grower (see following section). Pre-lay diets should only be used in an attempt at conditioning the calcium metabolism of the bird (see following section) and not as a means of initiating catch-up growth. Such growth spurts rarely occur at this age, and as such, pre-lay diets are being used as a "crutch" for poor rearing management.

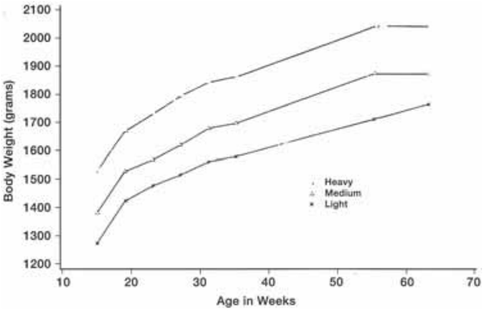
An argument that is often heard about the role of body weight at maturity is that it is not, in fact, too important, because the pullet will show catch up growth prior to first egg ie: if the pullet is small, it will take a few days longer to mature, and start production at the "same weight". This does not seem to happen, as small birds at 18 weeks are smaller at first egg (Table 8).

**Table 8. Effect of immature body weight on development to sexual maturity**

| Body weight (g) | | | Age at first egg (d) | Weight of first egg (g) |
|---|---|---|---|---|
| 18 weeks | 1st egg | Change | | |
| 1100 | 1360 | +260 | 153 | 40.7 |
| 1200 | 1440 | +240 | 150 | 42.0 |
| 1280 | 1500 | +22 | 149 | 43.7 |
| 1380 | 1590 | +210 | 148 | 42.5 |

These data suggest that the smaller pullet does show some compensatory growth to the time of the first egg, although this is insufficient to allow for total "catch-up" growth. It is also interesting to note the relationship between body weight and age at first egg, and also between body weight and size of first egg. In other studies, we have followed up on the growth of the pullet through a production cycle in relation to 18-week (immature) body weight. Again, there is a remarkably similar pattern of growth for all weight groups indicating that immature weight seems to "set" the weight of the bird throughout lay (Figure 3).

**Figure 3. Effect of immature body weight on subsequent body weight during lay.**



Most importantly from a production viewpoint, is the performance of birds shown in Figure 3. When the lightest weight birds were fed diets of very high nutrient density (20% CP, 3000 kcal ME/kg) they failed to match egg production and egg size of the largest weight pullets that were fed very low nutrient dense diets (14% CP, 2600 kcal ME/kg). These results emphasize the importance of body weight in attaining maximum egg mass output.

The actual body weights to be achieved during rearing will obviously vary with breed and strain. Most Leghorn strains should weigh around 400g, 900g and 1300g at six, 12 and 18 weeks respectively. Similarly, the brown egg birds should weigh around 500g, 1000g and 1500g at these ages. As a rule of thumb, these weights for age can be used as guidelines for anticipated diet change.

Discussion to date has focused on the role of body weight and appetite of the growing pullet. While rearing programs such as reverse-protein (Leeson and Summers, 1979) have application where delay in maturity is required (usually due to inadequate light control) nutritional management programs today must allow for maximum early growth so as to attain breeder's recommended weight goals as soon as possible. This type of nutritional management obviously entails accurate monitoring of body weight, a task that has too often been neglected with Leghorn pullets.

### *D. Manipulation Of Mature Body Size*

In the preceding discussion, we have outlined the importance of maximizing body weight at sexual maturity, and the reasons for this have been explained. Under certain conditions, it is realized that some tempering of mature body size may be economically advantageous. Because body size has a dramatic effect on egg side, large birds at maturity can be expected to produce large eggs throughout their laying cycle. Depending upon the pricing of various egg grades, a very large egg may be uneconomical to produce, and in most instances, tempering of egg size of birds at 40-65 weeks of age is often difficult to do without some accompanying loss in egg numbers. Because body weight controls feed intake and egg size, an easier way of manipulating life-cycle egg size is through the manipulation of mature body size. If the maximum possible egg size is desired, then efforts must be made to realize the largest possible mature weight. However, where a smaller overall egg size is economical, then a smaller pullet is desirable. Such light weight pullets can be achieved by growing birds slower through the growth cycle, or more economically by light-stimulating pullets at an earlier age.

### *E. Pre-lay Nutrition*

Pre-lay diets are often used to try and manipulate body size or to bring about a transitional change in the birds calcium metabolism prior to maturity.

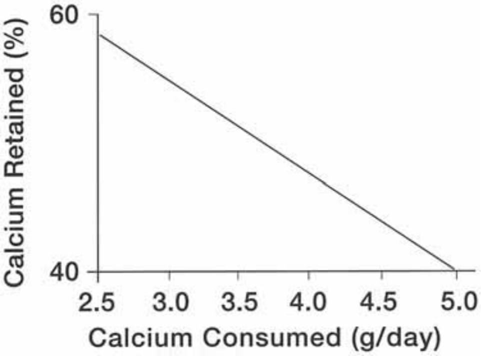
#### 1. Pre-lay calcium

There is still considerable confusion and variation practised in the levels of calcium given to birds prior to egg production. During the laying cycle, the bird utilizes its medullary bone reserves, in the long bones of the leg, to augment its diet supply when a shell is being formed. Because egg production is an "all or none" event, the production of the first egg obviously places a major strain on the bird's metabolism, when it has to contend with a sudden 2g loss of calcium from the body. Some of this calcium will come from the medullary bone, and so the concept has arisen of building up this bone reserve prior to first egg. This obviously means higher levels of calcium in pre-lay diets. There are basically three options for calcium feeding around the time of maturity.

#### *i. Use of 1% calcium grower diets until around 5% egg production*

As previously mentioned, the largest weight pullets in a flock will likely mature earlier, and so it is these birds that may be disadvantaged with inadequate levels of calcium at this time. If such birds receive a 1% calcium grower diet at the time they are producing their first few eggs, they will only have a sufficient calcium reserve to produce two to three eggs. At this time, they will likely stop laying, or less frequently continue to lay and exhibit cage layer fatigue. If these earlier maturing birds stop laying, they do so for four to five days, and then try to start the process again. The bird goes through very short clutches, when at this time she is capable of a very prolonged 30-40 egg first clutch. Advocates of prolonged feeding of grower diets suggest that it makes the bird more efficient in the utilization or absorption of calcium, such that when she is eventually changed to a layer diet, improved efficiency continues for some time, and so the bird has large quantities of calcium available for shell synthesis. Figure 4 indicates that percentage calcium absorption from the diet does decline with an increased level of calcium in the diet.

**Figure 4. Relationship between calcium intake and calcium retention.**



However, there is no scientific evidence to suggest that efficiency of utilization is affected, and in fact calculations from Figure 4 indicate that as the calcium level in the diet is increased, calcium retention increases even though percentage retention has declined.

If 1% calcium grower diets are used as pullets mature, these diets should not be used after appearance of first egg, and to 0.5% production at the very latest. It must be remembered that under commercial conditions, it is very difficult to precisely schedule diet changes, and so decisions for diet change need to precede actual time of diet change, such that production does not reach 5-10% before birds physically receive the calcium enriched diets.

*ii. Use of 2% calcium pre-lay diets*

Specialized pre-lay diets are a compromise, in that they provide more calcium than do most grower diets, but still not enough for sustained production. The concept of using so-called pre-lay diets is to build up the medullary reserves without adversely influencing general mineral metabolism. However, as previously discussed with grower diets, 2% calcium pre-lay diets are inadequate for sustained egg production, and should not be fed past 1% egg production. The main disadvantage of pre-lay diets is that they are used for a short period of time, and many producers do not want the bother of handling an extra diet at the layer farm. There is also reluctance by some producers with multi-age flocks at one site to use pre-lay diets, where delivery of diets with 2% calcium to the wrong flock on site can have disastrous effects on production.

**Table 9. Effect of % diet calcium fed to birds immediately prior to lay, on calcium retention.**

| Diet Ca (%) | Daily Ca retention | Excreta Ca (% dry matter) |
|---|---|---|
| 0.9 | 0.35 | 1.4 |
| 1.5 | 0.41 | 3.0 |
| 2.0 | 0.32 | 5.7 |
| 2.5 | 0.43 | 5.9 |
| 3.0 | 0.41 | 7.5 |
| 3.5 | 0.51 | 7.7 |

*iii. Early introduction of 3.5 - 4.0% calcium layer diets*

In terms of calcium metabolism, the most effective program is early introduction of the layer diet. Such high calcium diets allow sustained production of even the earliest maturing birds. As previously mentioned, higher calcium diets fed to immature birds, lead to reduced percentage retention, although absolute retention is slightly increased (Table 9).

Feeding layer diets containing 3.5% calcium prior to first egg, therefore results in a slight increase in calcium retention of about 0.16 g/day relative to birds fed 0.9% calcium grower diets at this time. Over a 10-day period, however, this increased accumulation is equivalent to the output in one egg.

Early introduction of layer diets is therefore beneficial in terms of optimizing the calcium balance of the bird. However, there has been some criticism leveled at this practice. There is the argument that feeding excess calcium prior to lay imposes undue stress on the bird's kidneys, since this calcium is in excess of the immediate requirement and must be excreted. In the study detailed in Table 9, we do show increased excreta calcium. However, kidney histology from these birds throughout early lay revealed no changes due to pre-lay calcium feeding. Recent evidence suggests that pullets must be fed a layer diet from as early as six to eight weeks of age before any adverse effect on kidney structure is seen (see following section on urolithiasis). It seems likely that the high levels of excreta calcium shown in Table 9 reflect fecal calcium, suggesting that all excess calcium may not even be absorbed into the body, merely passing through the bird with the undigested feed. This is perhaps too simplistic a view, since there is other evidence to suggest that excess calcium may be absorbed by the immature bird at this time. Such evidence is seen in the increased water intake and excreta water content of birds fed layer diets prior to maturity.

**Table 10. Effect of prelay calcium level on excreta moisture (%).**

| Prelay diet Ca | Bird age (days) | | | |
|---|---|---|---|---|
| | 147 | 175 | 196 | 245 |
| 1% | 71.4 | 78.7 | 75.3 | 65.5 |
| 2% | 71.6 | 77.2 | 73.9 | 63.9 |
| 3% | 72.1 | 77.7 | 74.1 | 63.9 |
| 4% | 77.0 | 80.0 | 76.0 | 69.4 |

Early introduction of a layer diet seems to result in increased water intake, and a resultant increase in excreta moisture. Unfortunately, this increased water intake and wetter manure seems to persist throughout the laying cycle of the bird (Table 10).

These data suggest that birds fed high calcium layer diets during the pre-lay period will produce manure that contains 4-5% more moisture than birds fed 1% calcium grower or 2% calcium pre-lay diets. There are reports of this problem being most pronounced under heat stress conditions. A 4 to 5% increase in manure moisture may not be problematic under some conditions, although for those farms with a chronic history of wet layer manure, this effect may be enough to tip the balance and produce a problem.

In summary, the calcium metabolism of the earliest maturing birds in a flock should be the criterion for selection of calcium levels during the pre-lay period. Prolonged feeding of low-calcium diets is not recommended. Early introduction of layer diets is ideal, although where wet manure may be a problem, a 2% calcium prelay diet is recommended. There seems to be no problem with the use of 2% calcium prelay diets, as long as birds are consuming a high calcium layer diet not later than 1% egg production.

### *2. Pre-lay Body Weight And Composition*

Pre-lay diets are often formulated, and used, on the assumption that they will improve body weight and/or composition, and so correct problems arising with the previous growing program. Body weight and body condition should not really be considered in isolation, although at this time we do not have a good method of readily assessing body condition in the live pullet. For this reason, our main emphasis at this time is directed towards body weight.

The most important criterion used during rearing is pullet body weight as described previously. Each strain of bird has a characteristic mature body weight that must be reached or surpassed for adequate egg production and egg mass output. In general, pre-lay diets should not be used in an attempt to manipulate mature body size. The reason for this is that for most flocks, it is too late at this stage of rearing to meaningfully influence body weight - all too often, pre-lay diets are used as a crutch for poor rearing management.

However, if underweight birds are necessarily moved to a layer house, then there is perhaps a need to manipulate body weight prior to maturity. With black-out housing, this can sometimes be achieved by delaying photostimulation - this option is becoming less useful in that Leghorns and brown egg strains seem now to be maturing early without any light stimulation. If pre-lay diets are then necessarily used in an attempt to correct rearing mismanagement, then it seems as though the bird is most responsive to energy. This fact likely fits in with the effect of estrogen on fat metabolism, and the significance of fat used for liver and ovary development at this time. While such high nutrient density pre-lay diets may be useful in manipulating body weight, it must be remembered that this late growth spurt (if it occurs) will not be accompanied by any meaningful change in skeletal growth. This means that in extreme cases, where birds are very small in weight and stature at approximately 16 -18 weeks of age, then the end result of using high-nutrient dense pre-lay diets may well be pullets of correct body weight, but of small stature. These short shank length pullets seem more prone to prolapse/pick-out, and so this is another example of the limitations in use of classical pre-lay diets.

While body composition at maturity may well be as important as body weight at this age, it is obviously a parameter that is difficult to quantitate. There is no doubt that energy is likely the limiting nutrient for egg production for all strains of bird, and around peak production, feed may not be the sole source of energy. Labile fat reserves at this time are therefore, essential to augment feed sources that are inherently limited by low feed intake. These labile fat reserves become critical during situations of heat stress or general hot weather conditions. Once the bird starts to produce eggs, then its ability to deposit fat reserves is greatly limited. Obviously if labile fat reserves are to be of significance, then they must be deposited prior to maturity. As with most classes of bird, the fat content of the pullet can best be manipulated through changing the energy:protein balance of the diet. If labile fat reserves are thought necessary, then high energy, high fat pre-lay diets should be considered. As previously stated, this scenario could well be beneficial if peak production is to coincide with periods of high environmental temperature.

The requirements for a specific body composition at the onset of maturity have not been adequately established. With mammals, onset and function of normal estrus activity is dependent on the attainment of a certain body fat content. In humans for example, onset of puberty will not occur if body fat content is less than around 14%. No such clear cut relationship has emerged with egg layers. Work conducted with broiler breeders, in fact indicate a more definite relationship between lean body mass and maturity, rather than fat content and maturity.

### *3. Subsequent Egg Weight And Egg Composition*

It seems as though egg size is ultimately controlled by the size of the yolk that enters the oviduct. In large part this is influenced by body weight of the bird, and so factors described previously for body weight can also be applied to concerns with egg size. There is a general need for as large an early egg size as is possible, especially with breeder hens. Most attempts at manipulating early egg size have met with limited success. Increased levels of linoleic acid in prelay diets may be of some use, although levels in excess of the usual 1% found in most diets produce only marginal effects on early egg size. From a nutritional standpoint, egg size can best be manipulated with diet protein, and especially methionine concentration. It is logical, therefore to consider increasing the methionine levels in pre-lay diets.

For breeder hens, one also has to consider egg composition in relation to successful embryo development. It is well known that hatchability of eggs from young breeders is lower. The reasoning for this suboptimal hatch seems to relate to “maturity” of embryonic membranes, and movement of nutrients from the yolk and albumen to the embryo. However, part of this problem may also relate to inadequate passage of certain nutrients from the breeder hen into the egg. For example, it is known that young breeders do not deposit normal quantities of biotin into the egg - normal biotin concentration in the egg is apparently not achieved until production of the 8 - 10th egg. If this is a general effect with a number of key nutrients, then it would seem worthwhile to study the effect of pre-lay nutrient intake on egg composition in relation to embryonic needs.

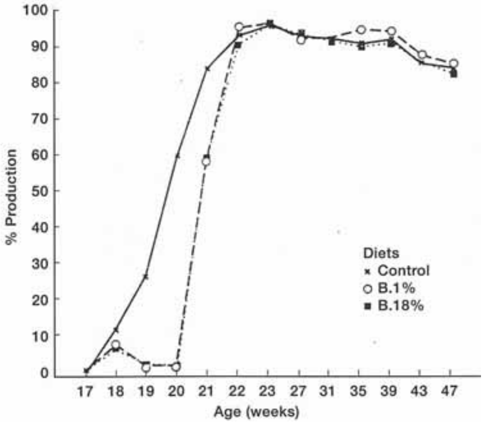
### *4. Pre-pause*

In recent years, there has been interest in some countries of so-called pre-pause feeding programs. The idea behind these programs is to withdraw feed, or feed a very low nutrient dense diet at time of sexual maturity. This somewhat unorthodox program is designed to “pause” the normal maturation procedure, and at the same time to stimulate greater egg size when production resumes after about 10-14 days. This type of pre-lay program is therefore most beneficial where early small egg size is undesirable.

Pre-pause can be induced by simply withdrawing feed, usually at around 1% egg production. Under these conditions, pullets immediately lose weight, and fail to realize normal weight-for-age when re-fed. Egg production and feed intake normalize after about 22 weeks, although there is 1-1.5g increase in egg size. Figure 5 shows the production response of Leghorn pullets fed only wheat bran from 18 weeks (1% egg production) through to 20 weeks of age. This data is presented on an equalized physiological basis, rather than equal age basis.

The most noticeable effects of a pre-pause diet such as wheat-bran, are very rapid attainment of peak egg production and an increase in egg size once re-feeding commences. These effects (Figure 5) are undoubtedly due to increased feed intake. This management system could therefore be used to better synchronize onset of production (due to variance in body weight), to improve early egg size or to delay production for various management related decisions. The use of such pre-pause management will undoubtedly be affected by local economic considerations.

**Figure 5. Early egg production of pullets fed wheat bran at 1% egg production or at 18 weeks of age.**



### *5. Urolithiasis*

Kidney dysfunction often leads to problems such as urolithiasis, and this most commonly occurs during the late growing or early egg production phase of the pullet. While infectious bronchitis can be a confounding factor, urolithiasis is most often induced by diet mineral imbalance in the late growing period. At post-mortem, often one kidney is found to be enlarged and contain mineral deposits known as uroliths. Some outbreaks are correlated with a large increase in diet calcium and protein in layer versus grower diets, coupled with the stress of physically moving pullets at this time, and being subjected to a change in the watering system (usually onto nipples in the laying cages). The uroliths are most often composed of calcium-sodium-urate.

The occurrence is always more severe when growing pullets are fed high calcium diets for an extended period prior to maturity. For example, urolithiasis causing 0.5% weekly mortality, often occurs under experimental conditions when pullets are fed layer diets after 10-20 weeks of age (relative to maturity at 18-19 weeks). However there is no indication that early introduction of a layer diet for just two to three weeks prior to maturity is a causative factor.

Because diet electrolytes can influence water balance and renal function, it is often assumed that an electrolyte excess or deficiency may be predisposing factors in urolithiasis or gout. Because salts of uric acid are very insoluble, then the excretion of precipitated urate salts could serve as a water conversation mechanism, especially when cations are excreted during salt loading or when water is in short supply. When roosters are given saline water (1% NaC1) and fed high-protein diets, uric acid excretion rates are doubled relative to birds offered the high protein diet al.,ong with non-saline drinking water. Because uric acid colloids are negative charges, they attract cations such as Na, and so when these are in excess, there is an increased excretion via urates, presumably at the expense of conventional NH4 compounds. There is some evidence of an imbalance of Na+K-C1 levels influencing kidney function. When excess Na+K relative to C1 is fed, a small percentage of the birds develop urolithiasis. It is likely that such birds are excreting a more alkaline urine, a condition which encourages mineral precipitation and urate formation.

Urolithiasis therefore seems to be most problematic in laying hens fed high levels of calcium well in advance of sexual maturity. Although the situation is often confounded with IBV infection, it seems obvious that no more than 1% calcium should be fed to Leghorn birds prior to maturity. Feeding pre-lay (2% Ca) or layer diets containing 3% calcium for two to three weeks prior to first egg is not problematic, and surprisingly, uroliths rarely form in adult male breeders fed high calcium diets. High levels of crude protein will increase plasma uric acid levels, and potentially provide conditions conducive to urate formation. Certainly numerous mycotoxins influence kidney function, and so general mill management regarding quality control and/or use of feed additives to suppress their harmful effects would likely be beneficial.

In humans at least, urolith formation can be controlled by adding urine acidifiers to the diet. Studies with pullets show similar advantages. Adding 1% NH4C1 to the diet results in a more acidified urine, and uroliths rarely form under these conditions. Unfortunately, this treatment results in increased water intake and associated wet manure. One of the potential problems in using NH4C1 in laying hens, is that it induces a metabolic acidosis and this is detrimental to egg shell quality especially under conditions of heat stress. Such treatment also assumes the kidney can clear the increased load of H+, and for a damaged kidney, this may not always occur. As a potential urine acidifier without such undesirable side effects, several researchers have studied the role of Alimet® a methionine analogue. From five to17 weeks of age, pullets were fed diets containing 1 or 3% calcium in combination with 0, 0.3 or 0.6% Alimet®. Birds fed the untreated high calcium diet excreted alkaline urine containing elevated calcium concentrations together with urolith formation and some kidney damage. Feeding 0.6% Alimet® acidified the urine, but did not cause a general metabolic acidosis. Alimet® therefore reduced kidney damage and urolith formation without causing acidosis or increased water consumption.

It is concluded that urine acidification can be used as a prevention or treatment of urolithiasis, and that this can be accommodated without necessarily inducing a generalized metabolic acidosis. From a nutritional viewpoint, kidney dysfunction can be minimized by not oversupplying nutrients such as calcium, crude protein and electrolytes for too long a period prior to maturity.

### *F. Brown-egg Pullets*

There is very little information available on specific nutrient needs of brown egg pullets, and whether or not they need diets any different to those used for white egg birds. It is generally assumed that white and brown egg pullets are similar in their nutrient needs relative to body weight. Brown egg pullets are usually heavier than white egg birds, although this difference seems to be decreasing over the last few years. For example, in the past it has been fairly common practice to start physical feed restriction after 10-12 weeks of age, in order to control growth rate. Today, with many strains of pullet, this feed restriction is unnecessary, and in fact may be detrimental in hot weather conditions. The principle of feeding management of brown egg pullets is essentially the same as described for the slightly smaller white egg bird as outlined in the previous sections. Achieving target weight-for-age must be the major criterion of the growing program, because this ensures the best chance of realizing the bird's genetic potential as a layer.

If physical feed restriction is necessary, due to birds becoming overweight, then bird uniformity becomes a major concern. With a mild restriction program, birds can be allowed to "run-out" of feed one day per week and, usually this will do little harm to uniformity. If it is necessary to impose a greater degree of feed restriction, on a daily basis, then it is important to ensure rapid and even feed distribution, much as subsequently discussed for broiler breeders. Feed restriction should be relaxed if birds are subjected to any stresses such as beaktrimming, vaccination, general disease challenge or substantial reduction in environmental temperature. An alternative management procedure for overweight birds, is to schedule an earlier light stimulation and move to layer cages (see Fig. 3.4). There is an indication that young brown egg pullets may not adjust feed intake too precisely in response to adjusting diet energy level (Table 11).

**Table 11. Response of brown and white egg pullets to diet energy level**

| | Body weight (g) | | | Feed intake (g) | | |
|---|---|---|---|---|---|---|
| **Brown egg** | **42$^{d}$** | **84$^{d}$** | **126$^{d}$** | **0-42$^{d}$** | **42-84$^{d}$** | **84-126$^{d}$** |
| 2750 kcal/kg | 410 | 1090 | 1590 | 1010 | 2700 | 3240 |
| 3030 kcal/kg | 450 | 1160 | 1660 | 1020 | 2700 | 3070 |
| **White egg** | | | | | | |
| 2750 kcal/kg | 380 | 953 | 1362 | 940 | 2490 | 3100 |
| 3030 kcal/kg | 360 | 940 | 1375 | 910 | 2360 | 2790 |

As energy level is increased at a fixed protein level (Table 11), a reduction in growth rate is sometimes seen because protein and amino acid intake are limited. Brown egg pullets seems to change their feed intake very little under these conditions, and consequently there is improvement in growth rate. In another study, pullets were fed diets at 2750 or 3000 kcal ME/kg. Over the 126 days growing period, brown egg pullets consumed 6% more energy when fed the high energy diet (20.6 versus 19.4 Mcal). Contrary to this increased energy intake, white-egg pullets consumed about 18 Mcal ME regardless of energy level in the diet.

An alternative scenario in explaining these results is that the heavier brown-egg pullet has reduced amino acid needs, and so when fed high energy diets there is less effect on amino acid intake relative to needs. In a series of studies, we have shown the brown egg pullet to grow quite well on very low levels of lysine relative to that recommended by most breeders (Table 12).

**Table 12. Response of brown egg pullets to diet lysine**

| 0-42d | | 84-126d | |
|---|---|---|---|
| **Diet lysine (%)** | **Body wt (g)** | **Diet lysine (%)** | **Body wt (g)** |
| 0.58 | 393 | 0.38 | 1467 |
| 0.68 | 434 | 0.46 | 1512 |
| 0.78 | 437 | 0.54 | 1464 |
| 0.88 | 434 | 0.62 | 1488 |
| 0.98 | 436 | 0.70 | 1515 |
| 1.08 | 414 | 0.78 | 1470 |
| 1.18 | 407 | 0.86 | 1521 |

*(diets at 2930 kcal ME/kg)*

Up to 42 days of age, the lysine requirement of the pullet seems to be 0.58 - 0.68% of the diet, which is substantially less than values of 0.9-1.0% as recommended by most breeders. From 84-126 days during the later phases of growth, there was no response to growth rate with more than 0.46% diet lysine. These experimental results suggest that under moderate environmental temperatures, it may be inadvisable to use high energy diets for growing brown egg pullets. On the other hand, assuming their response to diet energy is independent of temperature, then it may be easier to stimulate growth of these pullets under heat stress conditions, simply by increasing the nutrient density of the diet.

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